EFFECTS OF SHORT PERIOD ANGLE OF ATTACK OSCILLATION ON AIR-TO-GROUND WEAPONS DIVE DELIVERY ACCURACY

David Pierre Gauthier

NAVAL POSTGRADUATE SCHOOL

Monterey, California

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by

David Pierre Gauthier

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The perturbation angle of attack is a measure of the gunsight aimpoint error at any given time, if all other delivery parameters are met, and converts directly to weapon impact error.

Effects of Short Period Angle of Attack Oscillation on Air-to-Ground Weapons Dive Delivery Accuracy

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DEFINITIONS OF SYMBOLS

REFERENCE QUANTITIES

V_{T_0}	- total aircraft velocity in reference state	(ft/sec)
U_0	- aircraft velocity parallel to FRL in reference state	(ft/sec)
W_0	- aircraft velocity perpendicular to FRL in reference state	(ft/sec)
M_0	- aircraft reference Mach number	
Γ_0	- reference flight path angle	(radians)
Θ_0	- reference pitch angle	(radians)
α_0	- reference angle of attack	(radians)
m	- aircraft mass	(slugs)
W	- aircraft weight	(pounds)
ρ	- air density	(slugs/ft^3)
S	- wing area	(ft^2)
$\bar{c}$	- wing mean aerodynamics chord	(ft)
$\bar{q}$	- dynamic pressure	(lbs/ft^2)
g	- acceleration of gravity	(ft/sec^2)
I_y	- moment of inertia about y axis	(slug-ft^2)
ξ_0	- thrust incidence with FRL + α_0	(deg)
l_{th}	- perpendicular distance to thrust line from c.g.	(ft)
FRL	- longitudinal reference axis-fuselage reference line	
l_B	- longitudinal distance from c.g. to bobweight	(ft)

PERTURBATION QUANTITIES

γ	- perturbation flight path angle	(rad or deg)
θ	- perturbation pitch angle	(rad)
α	- perturbation angle of attack	(rad/milli-radians when refer to sight angle)
u	- perturbation velocity component along FRL	(ft/sec)
w	- perturbation velocity component perpendicular to FRL	(ft/sec)
q	- perturbation pitch rate	(radians/sec)
δ_S	- perturbation stabilator position	(rad-pos. L.E. up)

TOTAL QUANTITIES

Γ	- total flight path angle $\Gamma = \Gamma_0 + \gamma = \Theta$ - ALPHA	(rad/deg)
Θ	- total pitch angle $\Theta = \Theta_0 + \theta$	(rad)
ALPHA	- total FRL angle of attack ALPHA = $\alpha_0 + \alpha$	(rad/mils)
U	- total velocity compert along FRL $U = U_0 + u$	(ft/sec)
M	- total Mach number	

STABILITY AXIS DIMENSIONLESS COEFFICIENTS AND DERIVATIVES

$C_D = D/\bar{q}S$

$C_{D_\alpha} = \partial C_D/\partial\alpha$

$C_{D_M} = \partial C_D/\partial M$

$C_{D\delta_S} = \partial C_D/\partial\delta_S$

$C_L \quad = L/\bar{q}S$

$C_{L\alpha} \quad = \partial C_L/\partial\alpha$

$C_{L\dot{\alpha}} \quad = [2V_{T_0}/\bar{c}]\,\partial C_L/\partial\dot{\alpha}$

$C_{L_M} \quad = \partial C_L/\partial M$

$C_{L_q} \quad = [2V_{T_0}/\bar{c}]\,\partial C_L/\partial q$

$C_{L\delta_S} \quad = \partial C_L/\partial\delta_S$

$C_m \quad = m/qS\bar{c}$

$C_{m\alpha} \quad = \partial C_m/\partial\alpha$

$C_{m\dot{\alpha}} \quad = [2V_{T_0}/\bar{c}]\,\partial C_m/\partial\dot{\alpha}$

$C_{mM} \quad = \partial C_m/\partial M$

$C_{mq} \quad = [2V_{T_0}/\bar{c}]\,\partial C_m/\partial q$

$C_{m\delta_S} \quad = \partial C_m/\partial\delta_S$

BODY AXIS DIMENSIONLESS COEFFICIENTS AND DERIVATIVES

$C_X \quad = C_D \cos\alpha_0 - C_L \sin\alpha_0$

$C_{X\alpha} \quad = (C_{D\alpha} - C_L)\cos\alpha_0 - (C_D + C_{L\alpha})\sin\alpha_0$

$C_{XM} \quad = C_{DM}\cos\alpha_0 - C_{LM}\sin\alpha_0$

$C_{X\delta_S} \quad = C_{D\delta_S}\cos\alpha_0 - C_{L\delta_S}\sin\alpha_0$

$C_N \quad = C_L \cos\alpha_0 + C_D \sin\alpha_0$

$C_{N\alpha} \quad = (C_{L\alpha} + C_D)\cos\alpha_0 + (C_{D\alpha} - C_L)\sin\alpha_0$

$C_{N\delta_S} \quad = C_{L\delta_S}\cos\alpha_0 + C_{D\delta_S}\sin\alpha_0$

$C_{N\dot{\alpha}} \quad = C_{L\dot{\alpha}}\sin\alpha_0$

$$C_{NM} = C_{LM}\cos\alpha_0 + C_{DM}\sin\alpha_0$$

All moment coefficients and derivatives are the same for body axis as for stability axis.

BODY AXIS DIMENSIONAL DERIVATIVES

$$X_u = \frac{\rho S U_0}{m}\left(-\frac{M}{2}C_{XM} - C_X + \frac{W_0}{2U_0}C_{X\alpha}\right) \qquad (1/\text{sec})$$

$$X_\alpha = \frac{\rho S U_0^2}{m}\left(-C_{X\alpha} - \frac{2W_0}{U_0}\left(C_X + \frac{M}{2}C_{XM}\right)\right) \qquad (\text{ft/sec}^2\text{rad})$$

$$X_q = \frac{\rho S U_0 \bar{c}}{4m} C_{X_q} \qquad (\text{ft/sec rad})$$

$$X_{\delta_S} = \frac{-\rho S V_{T_0}^2}{2m} C_{X\delta_S} \qquad (\text{ft/sec}^2\text{rad})$$

$$Z_u = \frac{\rho S U_0}{m}\left(-\frac{M}{2}C_{NM} - C_N + \frac{W_0}{2U_0}C_{N\alpha}\right) \qquad (1/\text{sec})$$

$$Z_\alpha = \frac{\rho S U_0^2}{2m}\left(-C_{N\alpha} - \frac{2W_0}{U_0}\left(C_N + \frac{M}{2}C_{NM}\right)\right) \qquad (\text{ft/sec}^2\text{rad})$$

$$Z_{\dot\alpha} = \frac{\rho S U_0 \bar{c}}{4m} C_{N\dot\alpha} \qquad (\text{ft/sec rad})$$

$$Z_q = \frac{\rho S U_0 \bar{c}}{4m} C_{Nq} \qquad (\text{ft/sec rad})$$

$$Z_{\delta_S} = \frac{\rho S V_{T_0}^2}{2m} C_{N\delta_S} \qquad (\text{ft/sec}^2\text{rad})$$

$$M_u = \frac{\rho S U_0 \bar{c}}{I_y}\left(\frac{M}{2}C_{mM} + C_m - \frac{W_0}{2U_0}C_{m\alpha}\right) \qquad (1/\text{sec-ft})$$

$$M_\alpha = \frac{\rho S U_0^2 \bar{c}}{2I_y}\left(C_{m\alpha} + \frac{2W_0}{U_0}\left(C_m + \frac{M}{2}C_{mM}\right)\right) \qquad (1/\text{sec}^2\text{rad})$$

$$M_{\dot\alpha} = \frac{\rho S \bar{c}^2 U_0^2}{4 I_y V_{T_0}} C_{m\dot\alpha} \qquad (1/\text{sec})$$

$$M_q = \frac{\rho S V_{T_0} \bar{c}^2}{4 I_y} C_{mq} \qquad (1/sec)$$

$$M_{\delta_S} = \frac{\rho S \bar{c} V_{T_0}^{\;2}}{2 I_y} C_{m\delta_S} \qquad (1/sec^2)$$

$$T_u = \frac{M}{m V_{T_0}} \frac{\partial T}{\partial M} \qquad (1/sec)$$

CONTROL SYSTEM DIAGRAM TERMS

F_{ST}	- pilot stick force	(pounds)
F_B	- bobweight stick force	(pounds)
e_F	- F_{ST} - F_B	(pounds)
δ_{ST}	- control stick movement	(inches)
δ_{SST}	- stabilator movement due to stick travel	(radians)
δ_{SSAS}	- stabilator movement due to stab. aug. sys.	(radians)
$e_{\delta S}$	- δ_{SST} + δ_{SSAS}	(radians)
a_Z^B	- normal acceleration at bobweight	(ft/sec^2)
θ_c	- perturbation pitch angle commanded	(rad)
e_θ	- θ_c - θ	(radians)
γ_c	- perturbation dive angle commanded	(rad)

I. INTRODUCTION

The theory and practice of fixed gunsight, air-to-ground weaponry is well established and differs only slightly from one aircraft to another due to minor handling quality and weapons release system differences among aircraft. Just as well established is the analysis of impact error sensitivities to variation of actual from desired release parameters. Table I shows the desired release parameters and error sensitivities in the most widely used F-4 dive bomb delivery. It is not the purpose of this study to disagree with any of the release parameters for this or any other delivery maneuver, but rather to demonstrate that increased emphasis in training on one of the error sensitivity categories, that of gunsight placement as influenced by FRL angle of attack perturbations, can greatly increase pilot competence in air-to-ground weapons delivery.

A lack of emphasis on angle of attack input to gunsight picture seems justified on the surface, since everything which is an input to sight angle can be computed and set prior to the delivery maneuver and should not be subject to error. In addition, Table I shows that the impact error due to a sight picture error on one mil (0.1% of a radian) is smaller than the impact error due to an airspeed error of 10 knots, or a flight path dive angle error of one degree. For these reasons and since only one FRL angle of

Table I.

Desired Delivery Parameters and Error Sensitivities for Maneuver Studied

Release Parameters	
Dive Angle	40 Degrees
Release Airspeed	500 KTAS
Release Height	5000 Feet AGL
Sight Angle	116 Mils
Release Horiz Range	4720 Feet
Release Slant Range	6875 Feet
Parameter Error	**Impact Error**
Dive Angle	
1° Steep	33 Feet long
1° Shallow	35 Feet short
Release Height	
100 Feet High	13 Feet short
100 Feet Low	13 Feet long
Release Airspeed	
10 KTS Fast	35 Feet long
10 KTS Slow	37 Feet short
Sight Angle/Aim Point	
+ 1 Mil/1 Mil Long	10 Feet long
- 1 Mil/1 Mil Short	10 Feet short

(This information was calculated from data in Ref. 3. Sight angle includes weapon trajectory drop, FRL angle of attack and gunsight parallax correction.)

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attack is associated with one steady flight condition at a given weight and configuration, it has been accepted that the angle of attack input to the sight setting is a quantity which varies only with release airspeed and dive angle. This is true, however, only if the aircraft is free from all longitudinal oscillations rising from the most recent atmospheric disturbance or if longitudinal control action were taken.

Most of the emphasis given to sight error due to angle of attack perturbations in the past can be summed up in the statement: "The aircraft must be in one-G flight at release in order for pipper placement to be an accurate indication of bomb impact point." Very little emphasis has been placed on the fact that a finite time interval must expire after the most recent longitudinal control input before the actual FRL angle of attack matches the steady state angle of attack for the desired flight condition. If bomb release occurs during this finite interval, any difference between perturbed FRL angle of attack and angle of attack computed for the sight setting will manifest itself as a bomb impact error. Finding the magnitude and duration of this angle of attack perturbation after making various dive angle error corrections was the purpose of this investigation.

II. PROBLEM SET-UP

The standard F-4 visual dive delivery of the MK 82 LDGP Bomb with conical fins was chosen for the investigation. This maneuver involves a roll-in from 12,000 feet at 400 KTAS on a heading 90° to desired run-in line. Roll-in is accomplished by a 135° bank angle descending turn to a 40° dive along the run-in line. Roll-in is accomplished at military power and completed by approximately 10,000 feet. Power is reduced to idle at 430 KTAS (at approximately 9,000 feet), and the aircraft accelerates at idle power in the 40° dive to 500 KTAS at the release altitude of 5,000 feet AGL.

The largest impact error in range is due to dive angle error at release. The causes for this error, shown in Figure 1, are:

1. In a dive angle other than 40°, with the gunsight pipper on the target, the range to the target is different than that planned for at 5,000 feet, while the bomb range from this point is approximately the same as if in the planned dive angle.

2. The FRL angle of attack is dependent on dive angle, but the input to the gunsight for angle of attack is based on a 40° dive angle.

In this study, pilot detection of a dive angle error at 9,000 feet (a typical point to detect an error, shortly after roll-out on final run in line) caused the pilot to

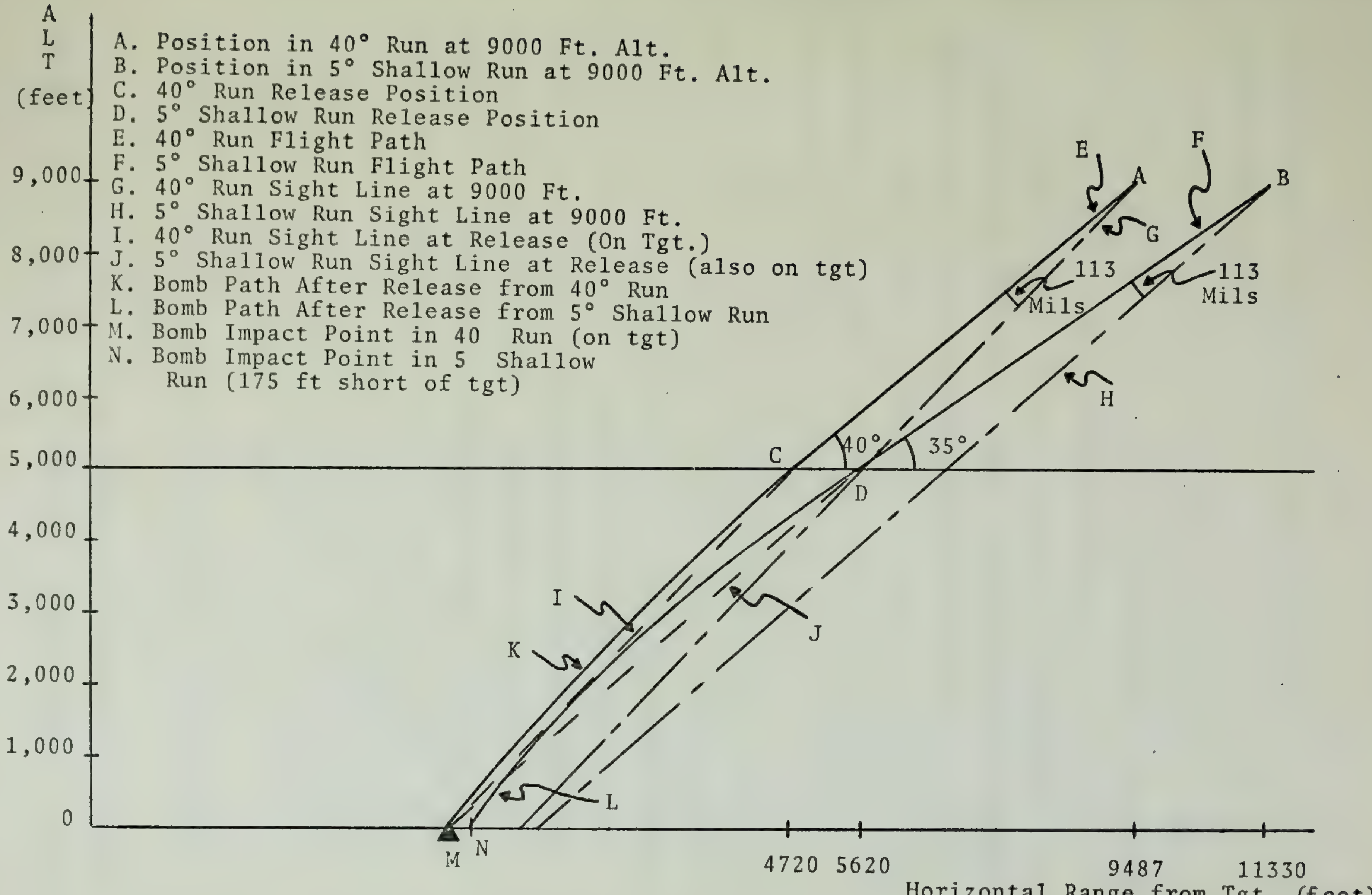


Figure 1. Diagram of 40° Run and 5° Shallow Run with 40° Sight Setting.

make an additional dive angle change to correct for the error in dive angle.

There are two different situations which can be considered to be the same dive angle error. A five degree shallow error exists for either of the following cases:

1. The pipper placement is correct for 9,000 feet altitude but the aircraft dive angle, as noted visually outside the aircraft or on the aircraft attitude indicator, is 35°.

2. The aircraft is actually in a 40° dive but the pipper placement at 9,000 feet altitude is 5° short of where it should be on the ground at that point.

In either case the aircraft is approximately 1,850 feet (horizontal range) farther from the target than it should be at that altitude in the maneuver, and the pilot must shallow the dive still further to re-position the aircraft on the proper flight path over the ground, and then re-establish the desired 40° dive angle. Since pilots rapidly acquire skill at rolling into a desired dive angle, the normal dive angle error situation is to be in a 40° dive but find the pipper aimed too far short or not short enough of the target at the 9,000 feet altitude check point. This was the case considered in this investigation.

A. DIFFERENCES BETWEEN ACTUAL MANEUVER AND COMPUTER SIMULATION

1. Actual Maneuver

In an actual run the aircraft is constantly increasing airspeed from approximately 430 KTAS at 9,000 feet to 500 KTAS

at 5,000 feet with changing lift and drag coefficients. Air density increases as altitude decreases and typically target elevation is not at sea level.

2. <u>Computer Simulation</u>

In the computer simulation it was assumed that release airspeed was attained at 9,000 feet and no further acceleration was achieved during the runs except as a result of perturbations due to longitudinal maneuvering. Since the assumed quasi-steady state velocity is the actual desired release velocity, results in the area of release altitude were very accurate. Air density was assumed constant at standard day density for 7,000 feet M.S.L., the mid-altitude for the run. Target elevation was assumed to be standard sea level. Other assumptions and conventions used were:

a. Flat earth fixed in space,

b. Atmosphere fixed to earth (no wind),

c. Rigid airframe,

d. Body axis system along FRL used throughout,

e. X-Z plane of symmetry, and

f. Small perturbation angles and velocities.

B. REPRESENTATION OF AIRFRAME DYNAMICS

The following body axis force equation system was obtained from Ref. 1 in the Laplace domain,

$$\begin{bmatrix} S-X_u-T_u\cos\xi & -X_\alpha & (W_0-X_q)S+g\cos\Theta_0 \\ -Z_u+T_u\sin\xi & (U_0+Z_{\dot\alpha})S-Z_\alpha & -(U_0+Z_q)S+g\sin\Theta_0 \\ -M_u+\dfrac{1_{th}}{I_y}T_u & -M_{\dot\alpha}+M_\alpha & S^2-M_qS \end{bmatrix} \begin{bmatrix} u \\ \alpha \\ \theta \end{bmatrix} = \begin{bmatrix} X_{\delta_S} \\ Z_{\delta_S} \\ M_{\delta_S} \end{bmatrix} \delta_S$$

where notation and definitions are given in Appendix A. The above system is represented in the time domain by the following linear differential equations.

1. $\dot{u} = (X_u + T_u \cos\xi)u + X_\alpha \alpha - g\cos\Theta_0 \theta - (W_0 - X_q)g + X_{\delta_S} \delta_S$

2. $\dot{\alpha} = \dfrac{Z_u - T_u \sin\xi}{U_0 - Z_{\dot{\alpha}}} u + \dfrac{Z_\alpha}{U_0 - Z_{\dot{\alpha}}} \alpha - \dfrac{g\sin\Theta_0}{U_0 - Z_{\dot{\alpha}}} \theta + \dfrac{U_0 + Z_q}{U_0 - Z_{\dot{\alpha}}} q$

$+ \dfrac{Z_{\delta_S}}{U_0 - Z_{\dot{\alpha}}} \delta_S$

3. $\dot{\theta} = q$

4. $\dot{q} = (M_u + \dfrac{1_{th}}{I_y} T_u)u + M_{\dot{\alpha}} \dot{\alpha} + M_\alpha \alpha + M_q q + M_{\delta_S} \delta_S$.

Substitution of Equation 2 for $\dot{\alpha}$ into equation 4 yields the following time domain matrix differential equation in the perturbation quantities u, α, θ and q.

$$\begin{bmatrix} \dot{u} \\ \dot{\alpha} \\ \dot{\theta} \\ \dot{q} \end{bmatrix} = \begin{bmatrix} X_u + T_u \cos\xi & X_\alpha & -g\cos\Theta_0 & X_q - W_0 \\ \dfrac{Z_u - T_u \sin\xi}{U_0 - Z_{\dot{\alpha}}} & \dfrac{Z_\alpha}{U_0 - Z_{\dot{\alpha}}} & \dfrac{-g\sin\Theta_0}{U_0 - Z_{\dot{\alpha}}} & \dfrac{Z_q + U_0}{U_0 - Z_{\dot{\alpha}}} \\ 0 & 0 & 0 & \\ M_u + \dfrac{1_{th}}{I_y} T_u + M_{\dot{\alpha}} \dfrac{Z_u - T_u \sin\xi}{U_0 - Z_{\dot{\alpha}}} & M_\alpha + M_{\dot{\alpha}} \dfrac{Z_\alpha}{U_0 - Z_{\dot{\alpha}}} & -M \dfrac{g\sin\Theta_0}{U_0 - Z_{\dot{\alpha}}} & M_q + M_{\dot{\alpha}} \dfrac{Z_q + U_0}{U_0 - Z_{\dot{\alpha}}} \end{bmatrix}$$

$$x \begin{bmatrix} u \\ \alpha \\ \theta \\ q \end{bmatrix} + \begin{bmatrix} X_{\delta_S} \\ \dfrac{Z_{\delta_S}}{U_0 - Z_{\dot{\alpha}}} \\ 0 \\ M_{\delta_S} + M_{\dot{\alpha}} \dfrac{Z_{\delta_S}}{U_0 - Z_{\dot{\alpha}}} \end{bmatrix} [\delta_S]$$

C. COMPUTER REPRESENTATION OF F-4 LONGITUDINAL CONTROL SYSTEM

Reference 1 contains diagrammatic representation of the individual components of the F-4 longitudinal control system as a linear control feedback system which can be combined to form the complete linear control system shown in Figure 2. Either Block Diagram Algebra or the Signal Flow Graph technique may be used to reduce the system in Figure 2 to the simplified closed loop system shown in matrix equation form in Figure 3. Derivation by Block Diagram Algebra techniques of the following Laplace domain representation of the control system is presented in detail in Appendix A.

$$(1+G_2G_3G_4H_1H_2(S) - G_4G_5H_3H_4(S))\delta_S(S) = G_1G_2G_3G_4(S)[\gamma_C-\gamma(S)].$$

As shown in Appendix A, precise representations in the Laplace domain of all the control system transfer functions would lead to a 42nd order differential equation, the numerical solution to which would be impractical for the purposes of this study. For this reason a method was sought to simplify the more complicated transfer functions which were not directly indicative of airframe dynamics: the aircraft feel system, defined $G_2(S)$; the stabilator actuator, defined $G_4(S)$; and the vertical acceleration feedback system to the Bobweight, defined $H_1(S)$. These simplifications are shown in Appendix A. The $\theta/\delta_S(S)$ transfer function, defined $G_5(S)$, although complicated, was not simplified since it represented actual airframe dynamic response to stabilator movement and its accuracy was considered critical to the investigation of

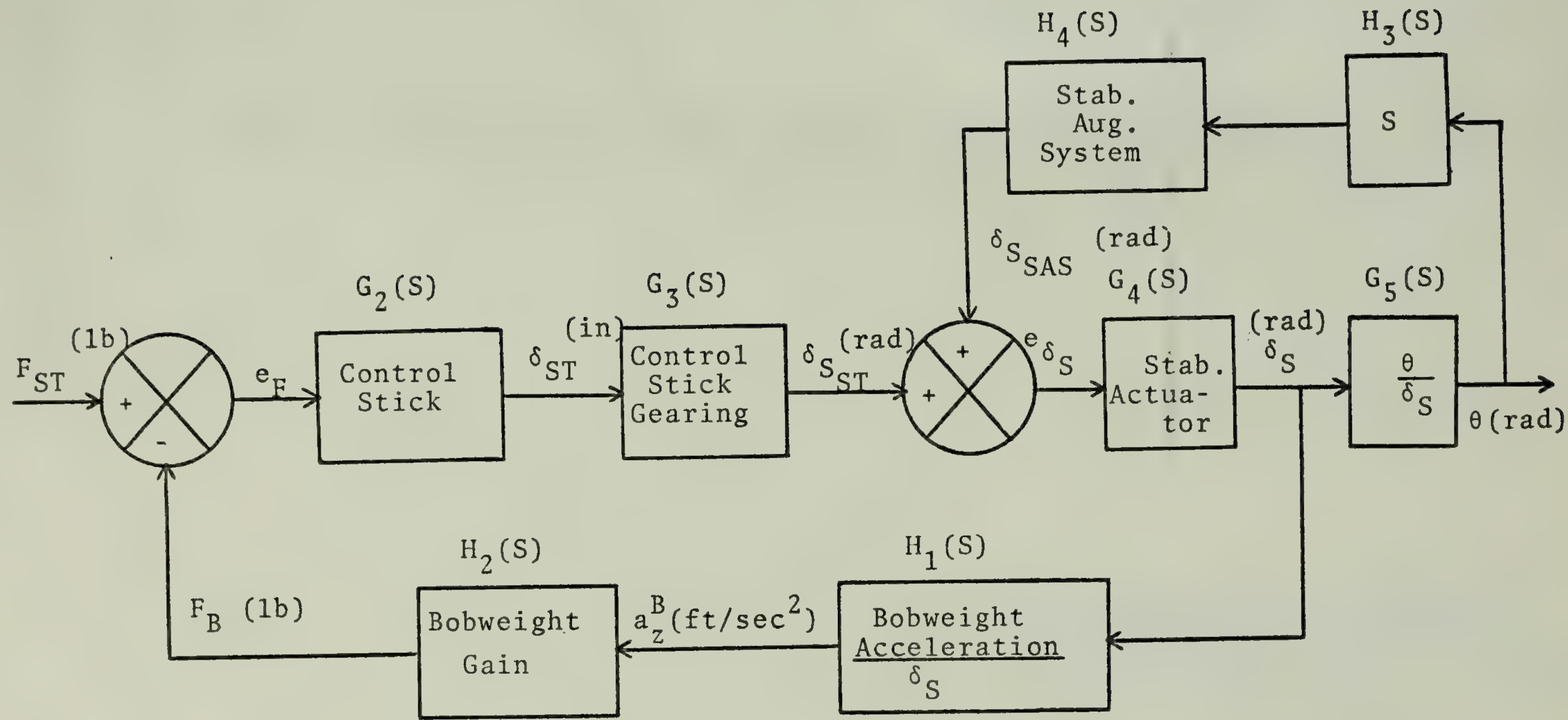


Figure 2. F-4 Longitudinal Control System.

$$
\begin{bmatrix} \dot{u} \\ \dot{\alpha} \\ \dot{\theta} \\ \dot{q} \\ \dot{x}_5 \\ \dot{x}_6 \\ \dot{x}_7 \\ \dot{x}_8 \\ \dot{x}_9 \end{bmatrix}
=
\begin{bmatrix}
X_u + T_u\cos\xi & X_\alpha & -g\cos\Theta_0 & X_q - W_0 & X_{\delta_S} & 0 & 0 & 0 & 0 \\
\frac{Z_u - T_u\sin\xi}{U_0 - Z_{\dot{\alpha}}} & \frac{Z_\alpha}{U_0 - Z_{\dot{\alpha}}} & \frac{-g\sin\Theta_0}{U_0 - Z_{\dot{\alpha}}} & \frac{Z_q + U_0}{U_0 - Z_{\dot{\alpha}}} & \frac{Z_{\delta_S}}{U_0 - Z_{\dot{\alpha}}} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
M_u + \frac{1\,th}{I_y} T_u + M_{\dot{\alpha}} \frac{Z_u - T_u\sin\xi}{U_0 - Z_{\dot{\alpha}}} & M_\alpha + M_{\dot{\alpha}} \frac{Z_\alpha}{U_0 - Z_{\dot{\alpha}}} & -M_{\dot{\alpha}} \frac{g\sin\Theta_0}{U_0 - Z_{\dot{\alpha}}} & M_q + M_{\dot{\alpha}} \frac{Z_q + U_0}{U_0 - Z_{\dot{\alpha}}} & M_{\delta_S} + M_{\dot{\alpha}} \frac{Z_{\delta_S}}{U_0 - Z_{\dot{\alpha}}} & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \\
0 & 0 & 0 & 0 & -a_9 & -a_8 & -a_7 & -a_6 & -a_5
\end{bmatrix}
\begin{bmatrix} u \\ \alpha \\ \theta \\ q \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \end{bmatrix}
$$

$$
+
\begin{bmatrix}
b_0 X_{\delta_S} \\
b_0 \frac{Z_{\delta_S}}{U_0 - Z_{\dot{\alpha}}} \\
0 \\
b_0 \left(M_{\delta_S} + M_{\dot{\alpha}} \frac{Z_{\delta_S}}{U_0 - Z_{\dot{\alpha}}}\right) \\
b_5 \\ b_6 \\ b_7 \\ b_8 \\ b_9
\end{bmatrix}
K_p \left(\gamma_c -
\begin{bmatrix} 0 \\ -1 \\ 1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}^T
\begin{bmatrix} u \\ \alpha \\ \theta \\ q \\ x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \end{bmatrix}
\right)
$$

Figure 3. Matrix Differential Equation for Aircraft Dynamics Coupled with Longitudinal Control System in Linear Control Feedback Form

the problem. With the above simplifications, the following equation is the Laplace domain representation for the stabilator position in terms of pilot stick force K_p and dive angle change required $(\gamma_c - \gamma)$. (See Appendix A for derivation.)

$$(S^5 + 18.45S^4 + 35.57S^3 + 95.0S^2 + 1.201S + 0.0224)\,\delta_S(S) =$$

$$- 0.01113K_p(S^5 + 3.802S^4 + 17.99S^3 + 16.37S^2 + 1.201S$$

$$+ 0.0224)[\gamma_c - \gamma(S)].$$

In the time domain this becomes the following fifth order linear differential equation:

$$\delta_S^{(5)} + 18.45\delta_S^{(4)} + 35.57\delta_S^{(3)} + 95.0\ddot{\delta}_S + 1.201\dot{\delta}_S + 0.0224\delta_S =$$

$$- 0.01113K_p[(\gamma_c - \gamma)^{(5)} + 3.802(\gamma_c - \gamma)^{(4)} + 17.99(\gamma_c - \gamma)^{(3)}$$

$$+ 16.37(\gamma_c \ddot{-} \gamma) + 1.201(\gamma_c \dot{-} \gamma) + 0.0224(\gamma_c - \gamma)].$$

The state space technique of Reference 5 for representation of nth-order systems of linear differential equations, in which the forcing function involves derivative terms, was used to cast the control system as a set of five linear first order differential equations, in general, for the following fifth order linear differential equation,

$$y^{(5)} + a_5y^{(4)} + a_6y^{(3)} + a_7\ddot{y} + a_8\dot{y} + a_9y =$$

$$- \beta_0^{(5)} + \beta_5u^{(4)} + \beta_6u^{(3)} + \beta_7\ddot{u} + \beta_8\dot{u} + \beta_9u$$

with the following definition of terms

$$x_5 = y - b_0 u$$

$$x_6 = \dot{x}_5 - b_5 u$$

$$x_7 = \dot{x}_6 - b_6 u$$

$$x_8 = \dot{x}_7 - b_7 u$$

$$x_9 = \dot{x}_8 - b_8 u$$

where b_0, b_5, b_6, b_7, b_8 and b_9 are defined by

$$b_0 = \beta_0$$

$$b_5 = \beta_5 - a_5 b_0$$

$$b_6 = \beta_6 - a_5 b_5 - a_6 b_0$$

$$b_7 = \beta_7 - a_5 b_6 - a_6 b_5 - a_7 b_0$$

$$b_8 = \beta_8 - a_5 b_7 - a_6 b_6 - a_7 b_5 - a_8 b_0$$

$$b_9 = \beta_9 - a_5 b_8 - a_6 b_7 - a_7 b_6 - a_8 b_5 - a_9 b_0$$

The matrix representation of the above set of linear differential equations is

$$\begin{bmatrix} \dot{x}_5 \\ \dot{x}_6 \\ \dot{x}_7 \\ \dot{x}_8 \\ \dot{x}_9 \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ -a_9 & -a_8 & -a_7 & -a_6 & -a_5 \end{bmatrix} \begin{bmatrix} x_5 \\ x_6 \\ x_7 \\ x_8 \\ x_9 \end{bmatrix} + \begin{bmatrix} b_5 \\ b_6 \\ b_7 \\ b_8 \\ b_9 \end{bmatrix} [u]$$

$$z = \{1\ 0\ 0\ 0\ 0\}\{x_5 x_6 x_7 x_8 x_9\}^T + b_0\ [u].$$

In the case of the control system, z is defined to be the stabilator position δ_S, and u is the forcing function $(\gamma_c - \gamma)$. The subscripts 5 through 9 were used since the control system equations were to be coupled with the four airframe equations of motion to form a ninth-order system for numerical solution.

D. AIRFRAME AND CONTROL SYSTEM COUPLED

The airframe and control system equation were coupled through δ_S, defined by $x_5 - K_p b_0(\gamma_c - \gamma)$. Using the fact that flight path angle Γ is defined by Γ = Θ-ALPHA and the flight path perturbation angle is defined by $\gamma = \theta - \alpha$, the final set of nine coupled linear differential equations appears as the feedback control system of Figure 3.

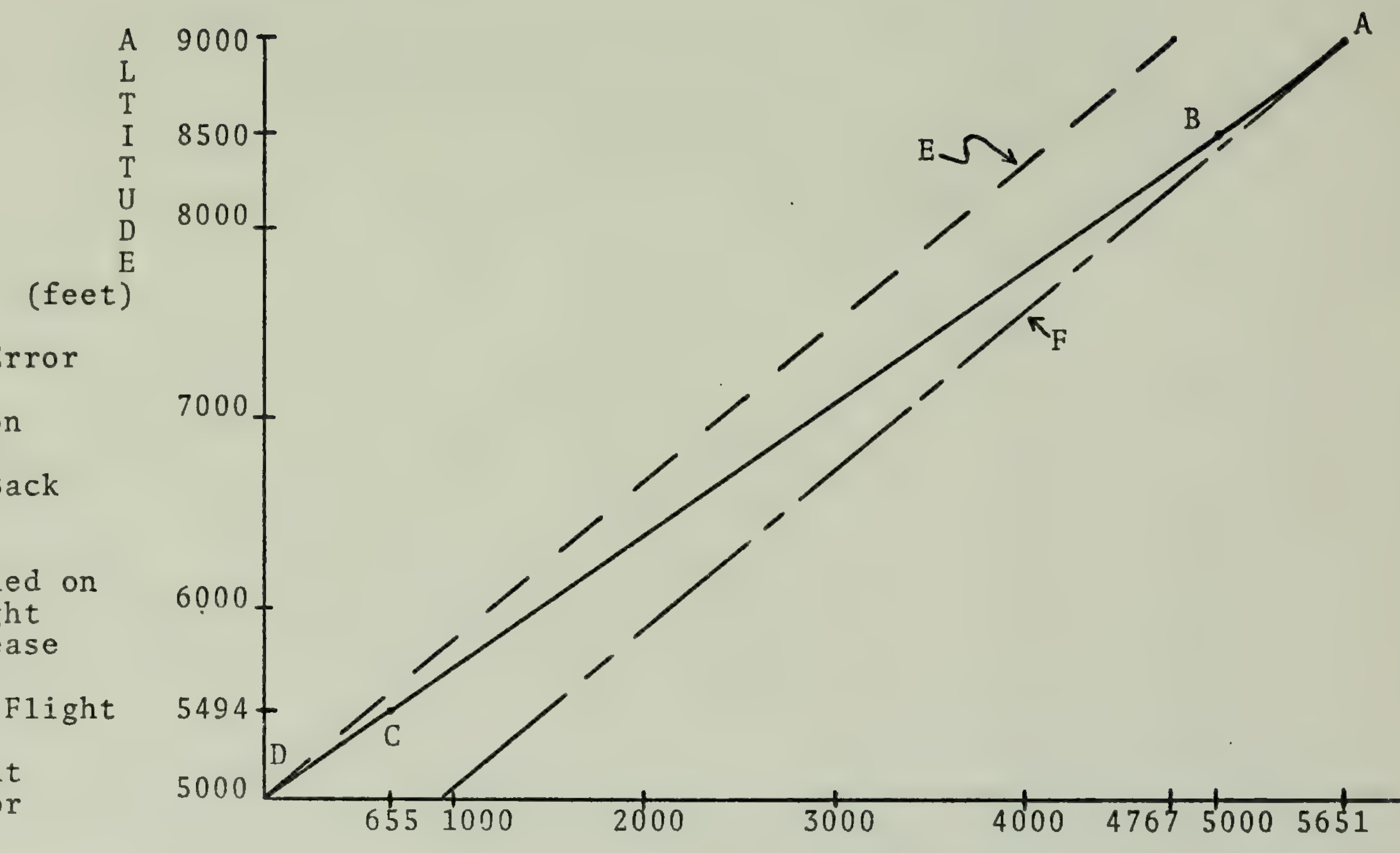
III. PROBLEM SOLUTION AND RESULTS

A. CASES CONSIDERED

Two separate initial conditions were treated. In the first case the pilot discovered at 9,000 feet that he was 2.2 degrees shallow of his desired flight path. In the second case he discovered that he 1.9 degrees steep of the desired track. For each dive angle error two alternative techniques were used to re-establish the desired 40° track over the ground. The first was to shallow or steepen further an amount which would allow re-establishment of the desired track immediately prior to the release altitude of 5,000 feet. The second technique was to shallow or steepen more than the first to allow re-establishment on the desired flight path early enough for the major protion of the air-frame short period oscillations to die out prior to the release altitude of 5,000 feet. Figures 4 through 7 illustrate the two error cases and the flight paths used to correct for these errors.

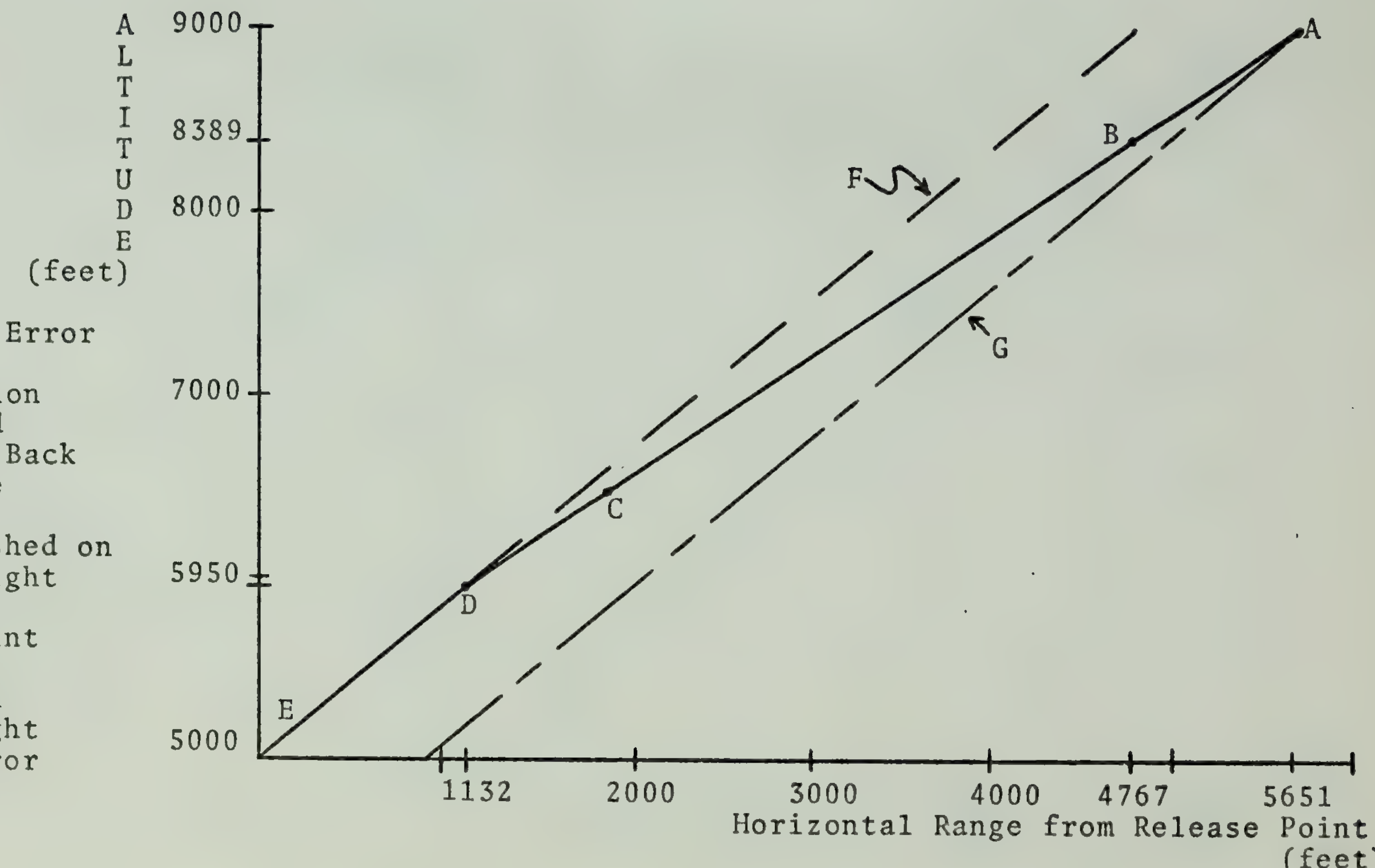
B. METHOD OF AIRCRAFT CONTROL

In shallowing or steepening the aircraft dive angle, the full system of nine equations was used to solve for the time response of u, α, θ, q and γ to the commanded perturbation dive angle γ_c. When the correction dive angle or the re-established 40° dive angle was approached, the reduced



A. Dive Angle Error Detected
B. 5° Correction Established
C. Transition Back to 40° Dive Commenced
D. Re-established on Desired Flight Path at Release Point
E. Desired 40° Flight Path
F. Actual Flight Path at Error Detection

Figure 4. Run 1, 2.2° Shallow, 5° Correction.



A. Dive Angle Error Detected
B. 8° Correction Established
C. Transition Back to 40° Dive Commenced
D. Re-established on Desired Flight Path
E. Release Point
F. Desired 40° Flight Path
G. Actual Flight Path at Error Detection

Figure 5. Run 2, 2.2° Shallow, 8° Correction.

A. Dive Angle Error Detected
B. 5° Correction Established
C. Transition Back to 40° Dive Commenced
D. Re-established on Desired Flight Path at Release Point
E. Desired 40° Flight Path
F. Actual Flight Path At Error Detection

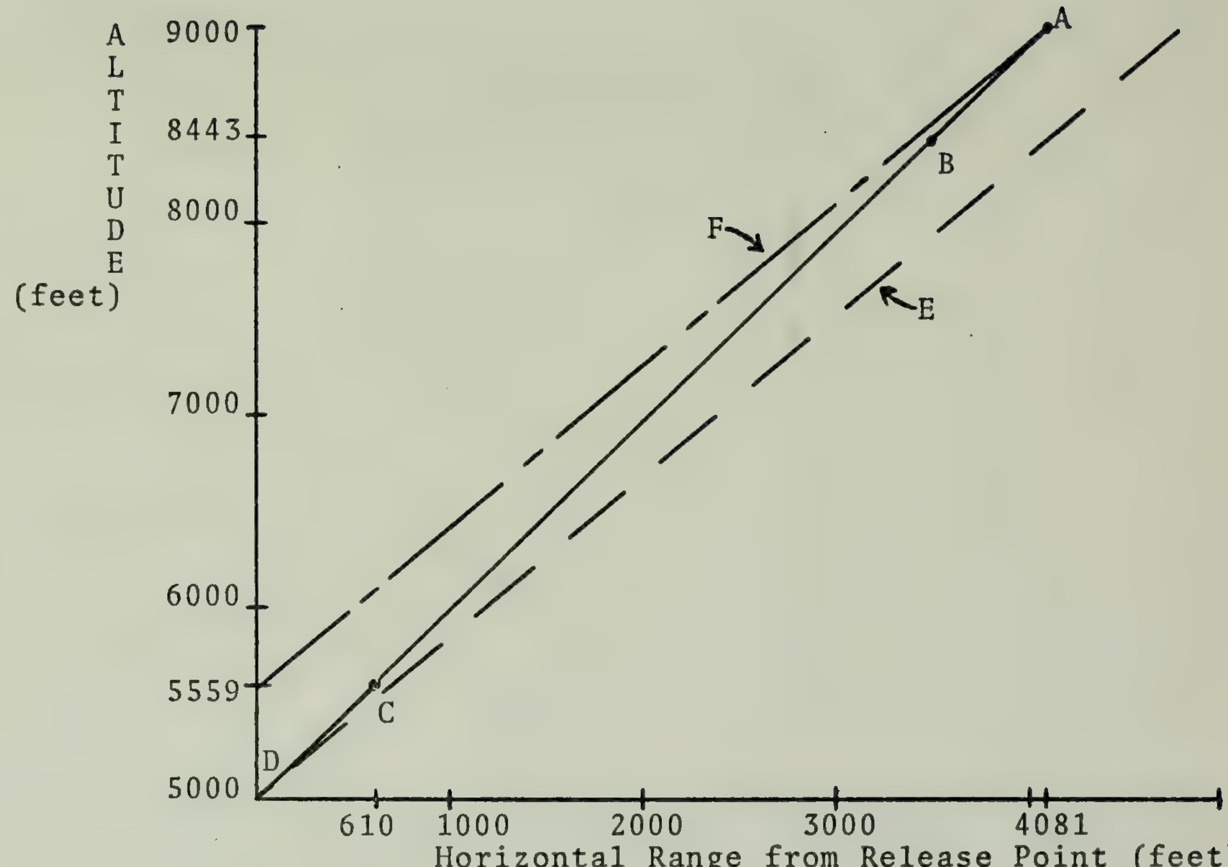
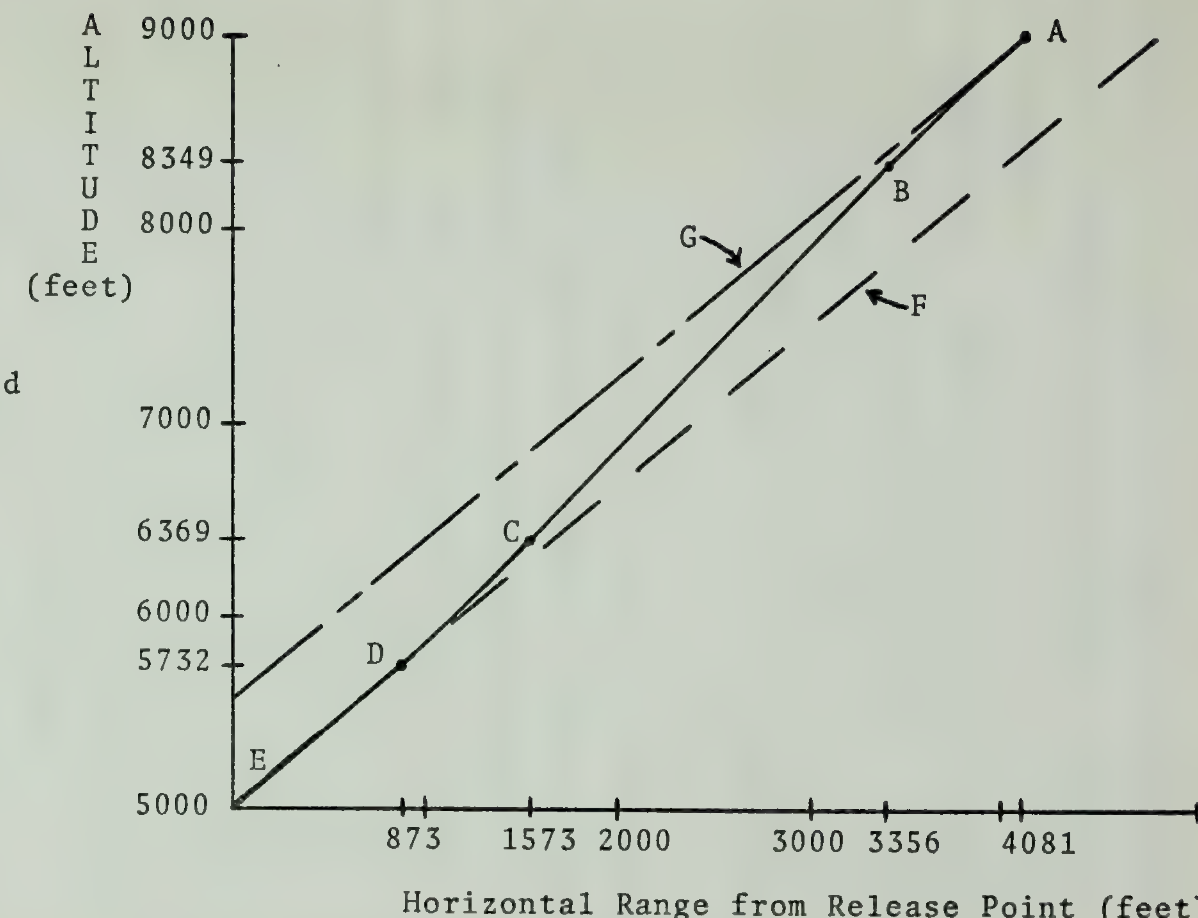


Figure 6. Run 3, 1.9° Steep, 5° Correction.



A. Dive Angle Error Detected
B. 8° Correction Established
C. Transition Back to 40° Dive Commenced
D. Re-established on Desired Flight Path
E. Release Point
F. Desired 40° Flight Path
G. Actual Flight Path at Error Detection

Figure 7. Run 4, 1.9° Steep, 8° Correction.

system consisting of only the four airframe equations was used to solve for the perturbation quantities. This was done for two reasons:

1. The simplified transfer functions of the longitudinal control system were invalid in the pitch rate range between -0.5° per second and 0.5° per second. Obviously a constant dive angle or zero pitch rate falls within this range.

2. Since it was the short period angle of attack perturbation which was of interest, the radian frequency for this mode of oscillation was such that airframe damping rather than pilot control movement is the factor which dampens the oscillation.

The pilot then flew the aircraft from the initial dive angle to the correction dive angle through the control system, anticipated achieving the new desired dive angle based on pitch rate and set the stabilator to the reference position (perturbation $\delta_S = 0$) for the new dive angle.

After the aircraft had flown the required time on the adjusted flight path to approach the correct 40° dive angle, the controlling sequence was repeated with the pilot re-establishing the 40° dive and the airframe dynamics in the new reference state maintaining it.

C. COMPUTER THEORY FOR AIRCRAFT CONTROL

Reference 6 contains computer programs for computational assistance in the study of linear control theory. The

programs used were GTRESP, CALCU, RUNGE, TRESP, YDOT, Y8VSX and user supplied subroutine RFIND. Program listings and explanation are contained in Appendix D. The purpose of the programs is to furnish the graphical time response to the following system:

$$\{\dot{x}(t)\} = [A]\,\{x(t)\} + \{b\}\,[u(t)]$$
$$[u(t)] = K(r(t) - \{k\}^T\,\{x(t)\})$$
$$y(t) = \{c\}^T\,\{x(t)\}.$$

In the case under consideration, {x} is the vector of perturbation quantities, [A] is the nine-by-nine or four-by-four plant matrix defining the airframe and control system, {b} is the control vector, $K \equiv K_p$ is the pilot stick force per radian of difference between actual and commanded dive angle, r is the commanded perturbation dive angle, {k} is the vector of feedback coefficients, and y is the actual perturbation dive angle made up of the output vector {c} multiplied by the airframe perturbation vector

$$(\gamma = \{0\ -1\ 1\ 0\}\{u\ \alpha\ \theta\ q\}^T).$$

Following is the detailed breakdown of one of the situations considered. At time zero the pilot at 9,000 feet altitude in a 40° dive determined that he was 885 feet horizontal range short of the correct position for that altitude in the delivery maneuver. This was equivalent to being 2.2° shallow. He elected to correct for this by shallowing 5°, flying at a 35° dive angle until approaching the desired track, steepening back to a 40° dive angle and flying at that 40° angle to release.

GTRESP was called with the following data:

1. the nine-by-nine plant matrix with airframe data referenced to a 40° dive angle and the control system,

2. the control vector,

3. the output vector,

4. the feedback coefficient vector,

5. K_p based on required dive angle change of 5°,

6. γ_c equal to +5° in radian measure, and

7. zero initial perturbation vector referenced to 40° dive conditions.

GTRESP then used the other subroutines to perform a fourth order Runge-Kutta integration to compute and plot the time response of the nine perturbation quantities.

At 0.975 seconds the perturbation dive angle was approaching 5° or Γ was approaching 35°. The airframe perturbation quantities for time equal to 0.975 seconds were transformed to perturbation quantities for a 35° dive reference state, and GTRESP was called with the following input data:

1. the reduced plant matrix of airframe data only referenced to a 35° dive,

2. the output vector, and

3. aircraft perturbation quantities referenced to 35° dive at time equal to 0.975 as the initial condition vector.

Failure to input the control vector, feedback coefficients, K_p and γ_c bypasses the control system which is not

accurate for zero and very small pitch rates and simulates the pilot controlling the aircraft by setting and maintaining the zero perturbation stabilator position for the 35° dive reference condition. Again GTRESP computes and plots the time response of the aircraft perturbation quantities.

At 7.2 seconds total elapsed time the aircraft was approaching the desired 40° track over the ground and GTRESP was called with the large plant matrix for control back to a 40° dive. Input was the same as for the first maneuver except that the aircraft dynamics portion of the nine-by-nine matrix was based on the 35° dive since that was the condition from which perturbations occurred, and the initial condition perturbations remained referenced to the 35° dive.

GTRESP computed and plotted the perturbation quantities through the transition back to a 40° dive. At 8.175 seconds total elapsed time the 40° dive on the correct flight path was re-established and it was simulated that the pilot neutralized longitudinal control by calling GTRESP, with the reduced plant matrix and initial perturbations transformed to those for a 40° dive reference state, to calculate and plot the perturbation dive angle, velocity, angle of attack, pitch angle, and pitch rate to release point.

On this particular run it was arranged to have the aircraft re-achieve the desired 40° dive angle at exactly the 5,000 feet release altitude. Therefore, the angle of

attack perturbation, converted to mils, existing at 8.175 seconds is in fact the release sight picture error that the pilot would have had on this maneuver at release altitude. Pertinent aircraft position and gunsight error information concerning each of the four bomb delivery maneuvers simulated is listed in Table II.

Computer output showing time history in tabular form of aircraft perturbation during the four phases of each of the four runs tested and in graphical form for the final delivery phase is enclosed in the Computer Output Section.

D. RESULTS OF THE FOUR RUNS

Table II shows that the total time available for maneuvering after detecting a dive angle error, 4,000 feet above release altitude, is very small for a 40° 500-knot dive bombing run. Therefore, any corrections made must be both timely and correct, if they are to succeed in increasing the accuracy of the bomb impact. Table II also shows that by merely increasing the correction dive angle from 5° to 8°, and thereby re-establishing the desired dive path 1.75 seconds prior to release rather than at release for the shallow run and 1.4 seconds prior to release rather than at release in the steep run, reduces the gunsight position error from 83 to 9 mils for the shallow case and from 80 to 3 mils for the steep case.

Examination of the graphical time histories of perturbation angle of attack, presented in Appendix C, shows that

RUN 1 2.2° Shallow 5° Correction	Alt. Lost (ft)	Height Above Release (ft)	Horizontal Distance Travelled (ft)	Horizontal Distance to Release (ft)	Total Elapsed Time (sec)	Sight Error at Release (mils)
Pull up to 35°	500	3500	652	4999	.975	-
35° Glide	3006	494	4344	655	7.2	-
Push over to 40°	494	0	655	0	8.175	-
40° Glide	-	-	-	-	-	83
RUN 2 2.2° Shallow 8° Correction						
Pull up to 32°	611	3389	884	4767	1.225	-
32° Glide	1819	1570	2896	1871	5.35	-
Push over to 40°	620	950	739	1132	6.575	-
40° Glide	950	0	1132	0	8.225	9
RUN 3 1.9° Steep 5° Correction						
Push over to 45°	557	3443	608	3473	.975	-
45° Glide	2884	559	2863	610	5.775	-
Pull up to 40°	559	0	610	0	6.75	-
40° Glide	-	-	-	-	-	80
RUN 4 1.9° Steep 8° Correction						
Push over to 48°	651	3349	725	3356	1.225	-
48° Glide	1980	1369	1783	1573	4.375	-
Pull up to 40°	637	732	700	873	5.575	-
40° Glide	732	0	873	0	6.925	3

Table II. Aircraft Position During Dive Angle Corrections and Gunsight Error at Release Alt.

any additional time spent on the desired dive path rapidly decreases the angle of attack perturbation, thereby rapidly increasing the accuracy of the gunsight position relative to actual bomb impact point.

IV. CONCLUSIONS AND RECOMMENDATIONS

Table II shows the elapsed time in each of the four weapons delivery maneuvers tested at which the aircraft finally becomes established in a 40° dive on the proper track over the ground for an accurate bomb hit. The Computer Output shows the FRL perturbation angle of attack at numerous time increments in each run. It is obvious for both the initially steep and initially shallow runs that the 5° correction dive angle, although sufficient to correct the aircraft back to desired dive path by release altitude, is not large enough to correct back to the desired dive path soon enough to allow for sight picture settling time, due to angle of attack oscillations of the short period longitudinal mode. However, by merely increasing slightly the magnitude of the correction dive angle change, it was possible to reposition the aircraft on the desired flight path early enough before the release point to allow time for the sight picture to stabilize sufficiently to achieve an acceptable bomb impact. Examination of the graphs showing time history of angle of attack perturbations during the final phase of the delivery maneuver shows that even earlier establishment on desired dive path is desirable and would increase the accuracy of the sight picture further.

In actual practice, a pilot on detecting a dive angle error would not consciously attempt to hold a dive angle

correction for a specific amount of time with the idea that in so doing he would re-establish his aircraft on the proper flight path. If he could do this, there would be no need for the gunsight. All the cases described herein would actually achieve very accurate bomb impacts, since for an aircraft at the correct velocity and in the desired dive angle along the proper path over the ground, very large angle of attack perturbations produce bomb impact errors only insofar as they change the aircraft dive angle. The error which would actually be produced in the case where all delivery parameters are met except for an angle of attack error would be that the gunsight reticle would be far off the target.

However, since the pilot in a visual dive bomb delivery uses visually acquired data for dive angle and aircraft positioning, he is entirely dependent on his gunsight for accurate aircraft positioning information; and during a period when he is receiving inaccurate gunsight information, he has no good indication of his position relative to the desired release position.

It has long been standard practice in visual air-to-air gunnery with a gyro-stabilized gunsight, which develops its own lead angle based on the normal acceleration of the firing aircraft required to track the target, to teach students not to squeeze the trigger until they have maintained a smooth tracking solution for two seconds on the target. This

was to allow angle of attack oscillations from a changing pitch rate to die out prior to firing.

The need to apply this same technique to visual air-to-ground delivery is just as important, or even more so when it is considered that a gyro-stabilized sight has inertia to decrease the magnitude of the effect of aircraft angle of attack perturbations; whereas the sight line of a mechanically fixed sight moves directly with angle of attack perturbations an amount equal to the movement of the FRL. Nor does a pilot in air-to-ground delivery have the option to wait until perturbations die out if this will take him below the planned release altitude, since the computed sight angle is good for only the planned delivery parameters. What he must do is to detect dive angle errors sufficiently early in the run and make corrections sufficiently large that all corrections are completed and all significant perturbations eliminated prior to the planned release height.

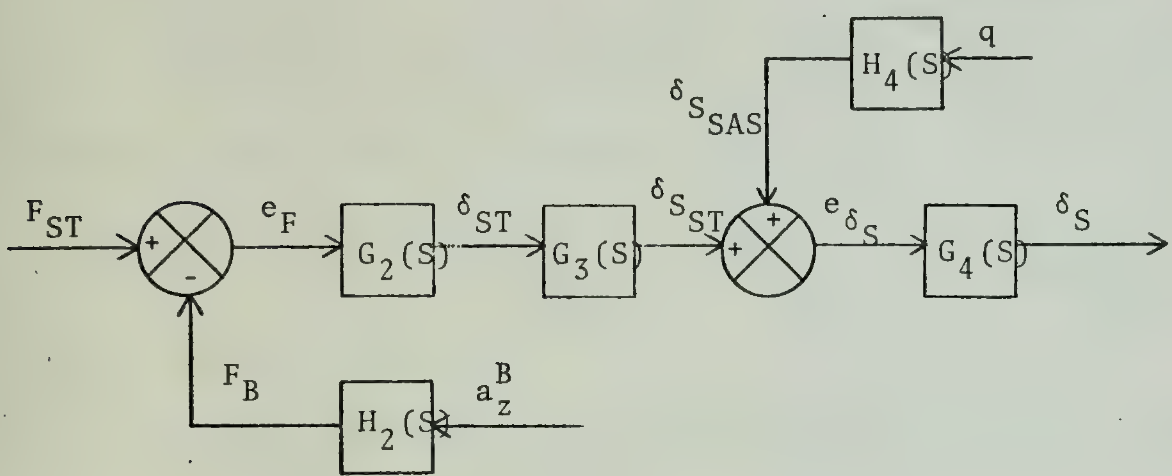
This study pertained specifically to the F-4 aircraft in a 40° dive, MK 82 LDGP Bomb, delivery. However, since all Navy fighter and light attack jet aircraft have similar short period characteristics with slight variance in damping ratio and oscillation frequency, and since all fixed-sight air-to-ground weapons delivery maneuvers have similar error sensitivities (differing only in the magnitude of the range error for each mil of aimpoint error), the results are applicable to all fixed gunsight, visual, air-to-ground weapons deliveries in all Navy tactical aircraft. As such, it is

recommended that similar studies be made to encompass all air-to-ground weapons deliveries from Navy tactical aircraft and the results be used in the lecture portions of air-to-ground training in both fleet and replacement squadrons. In addition a graphical display of the results herein can be easily demonstrated to a pilot in flight in the following manner. Trim the aircraft for steady level flight with the gunsight set on the distant horizon. Make a small but sharp longitudinal displacement of the control stick and return it to neutral. Notice that, although the change in aircraft track (speed and altitude) is extremely small, the magnitude of the gunsight oscillation above and below the horizon is significant; and that while the time to damp is short, it is long enough to lose several hundred feet, if it were in a 40° 500-knot dive.

Awareness of this phenomenon can do much to improve the proficiency of the not atypical pilot who, on being questioned about pipper placement after an unsuccessful air-to-ground weapons training flight, is not really able to tell an instructor where his pipper was positioned at release on most of his runs, this because of late corrections resulting in receipt of meaningless data from the gunsight.

APPENDIX A: DERIVATION OF LINEAR CONTROL FEEDBACK COMPUTER REPRESENTATION OF F-4 LONGITUDINAL CONTROL SYSTEM

The longitudinal control system of the F-4 aircraft is shown below in diagrammatical form,



where,

Feel System $\equiv G_2(S)=27.1\left[\frac{1}{S^2+5.637S+565.5}\right]\left(\frac{\text{inches stick travel}}{\text{pound force}}\right)$

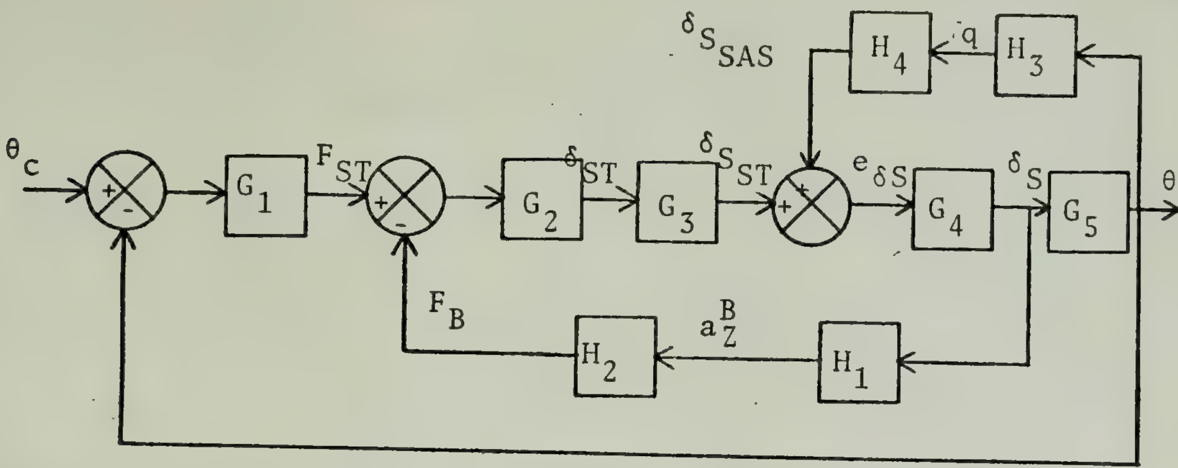
Control Stick Gearing $\equiv G_3(S)=-0.05864 \quad \left(\frac{\text{radians stabilator travel}}{\text{inch stick travel}}\right)$

Stabilator Actuator $\equiv G_4(S)= 20 \left[\frac{1}{S+20}\right]$

Bobweight $\equiv H_2(S)= 0.1663 \left(\frac{\text{pounds bobweight force}}{g}\right)$

Stab. Aug. System $\equiv H_4(S)= 0.15 \left[\frac{S}{S+1}\right]\left(\frac{\text{radians stabilator travel}}{\text{radian/sec pitch rate}}\right)$

With the addition of airframe dynamics and a pilot, modeled by K_p pounds of stick force per radian of error between actual and desired pitch angle, the representation becomes



where the additional transfer functions are,

Pilot force/radian $e_\theta \equiv G_1(S) = K_p$ $\left(\frac{\text{pounds force}}{\text{radian}}\right)$

a_Z^B/δ_S transfer function

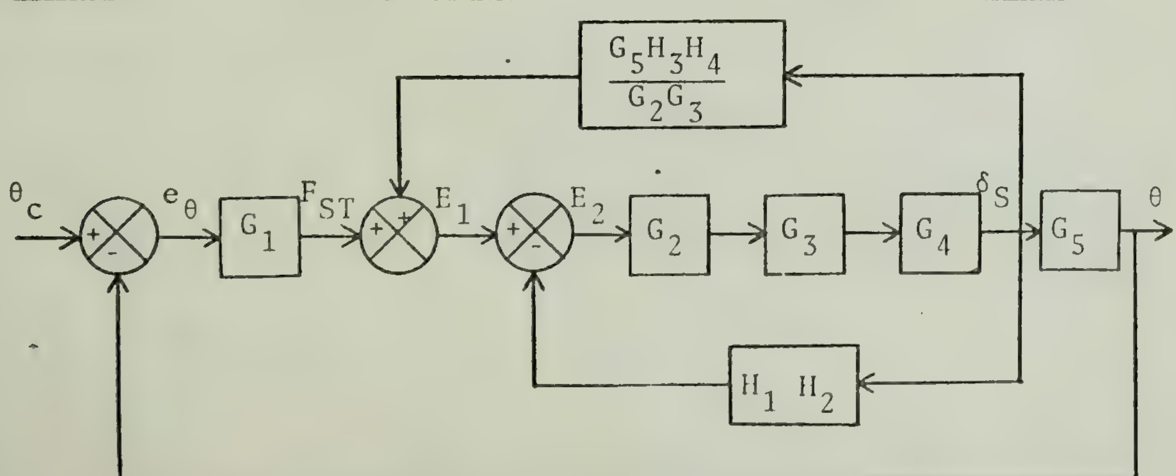
$$\equiv H_1(S) = 861.5\left[\frac{S^4+1.213S^3+27.98S^2+2.272S+0.04339}{S^4+2.802S^3+15.19S^2+1.179S+0.0224}\right]\left(\frac{g}{\text{radian}}\right)$$

θ/δ_S transfer function

$$\equiv G_5(S) = -24.64\left[\frac{S^2+1.2S+5.367}{S^4+2.802S^3+15.19S^2+1.179S+0.0224}\right]\left(\frac{\text{radian}}{\text{radian}}\right)$$

q/θ transfer function $\equiv H_3(S) = S$ $\left(\frac{\text{radian/sec}}{\text{radian}}\right)$

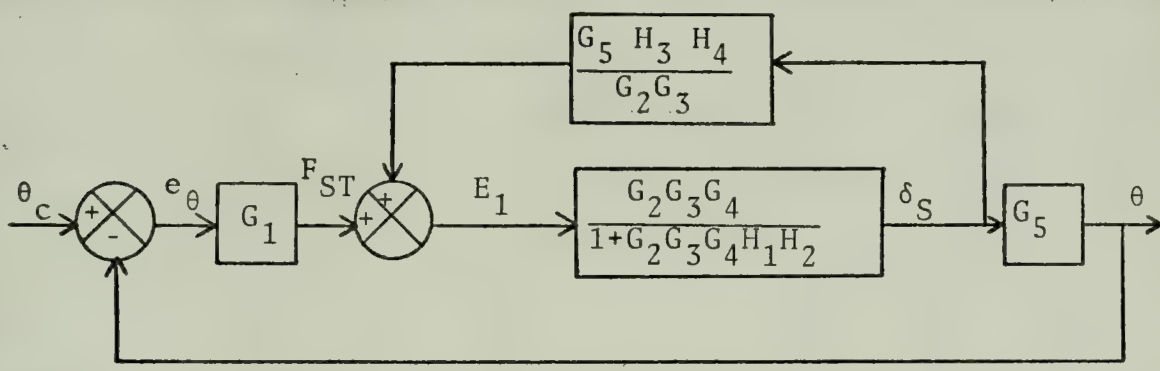
A block diagram algebra reduction of the control system as described in Reference 5 follows:



$$E_2 = E_1 - H_1H_2\delta_S$$

$$\delta_S = E_2G_2G_3G_4 = G_2G_3G_4E_1 - G_2G_3G_4H_1H_2\delta_S$$

$$\frac{\delta_S}{E_1} = \frac{G_2G_3G_4}{1 + G_2G_3G_4H_1H_2}$$

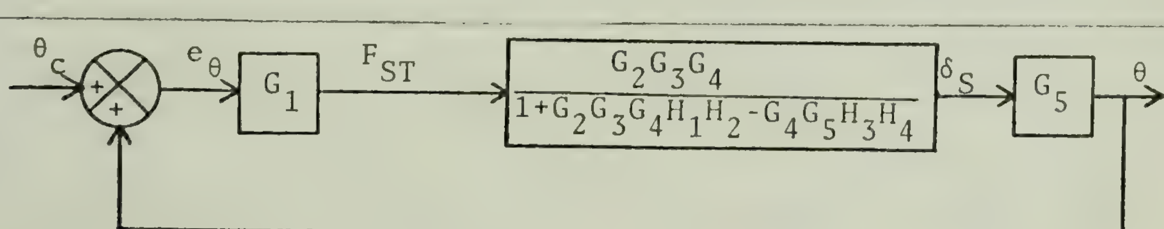


$$E_1 = F_{ST} + \frac{G_5H_3H_4}{G_2G_3}\ \delta_S$$

$$\delta_S = E_1\ \frac{G_2G_3G_4}{1 + G_2G_3G_4H_1H_2}$$

$$\frac{\delta_S}{F_{ST}} = \frac{\dfrac{G_2G_3G_4}{1 + G_2G_3G_4H_1H_2}}{1 - \dfrac{G_2G_3G_4G_5H_3H_4}{G_2G_3(1+G_2G_3G_4H_1H_2)}}$$

$$\frac{\delta_S}{F_{ST}} = \frac{G_2G_3G_4}{1 + G_2G_3G_4H_1H_2 - G_4G_5H_3H_4}$$



$$e_\theta = \theta_c - \theta$$

$$F_{ST} = e_\theta G_1 = G_1(\theta_c - \theta)$$

$$\delta_S = F_{ST} \frac{G_2G_3G_4}{1 + G_2G_3G_4H_1H_2 - G_4G_5H_3H_4}$$

$$\delta_S = \frac{G_1G_2G_3G_4(\theta_c - \theta)}{1 + G_2G_3G_4H_1H_2 - G_4G_5H_3H_4}$$

$$(1 + G_2G_3G_4H_1H_2 - G_4G_5H_3H_4)\ \delta_S(S) = G_1G_2G_3G_4[(\theta_c - \theta)(S)]$$

In this final form the control system in the Laplace domain can be readily transformed to its state space representation of a linear differential equation for δ_S as a function of time and $(\theta_c - \theta)$. However reducing all the transfer functions which are polynomial fractions in S to a least common denominator would result in a forty second order linear differential equation. Therefore, representation of some of the transfer functions that would yield a resulting differential equation more amenable to numerical solution but still accurate, was sought.

$\frac{\theta}{\delta_S}(S) \equiv G_5(S)$ was not disturbed since it represented actual airframe dynamics which was under investigation. Neither was the Stab. Aug. System $\equiv H_4(S)$. However, a frequency response investigation of the control stick $\equiv G_2(S)$, the stabilator actuator $\equiv G_4(S)$ and $a_Z^B \equiv H_1(S)$, using the FRESP computer program of Reference 6, yielded Bode Diagrams of transfer function magnitudes and phase angles showing that over the pitch rate range of interest (0.01 to 0.2)

radians/second - a normal acceleration range up to ± 5.2) the above transfer functions could accurately be represented by constant magnitudes with zero phase angle.

With these simplifications, the transfer functions are as follows:

$$G_1(S) = K_p \qquad H_1(S) = 1600$$

$$G_2(S) = 0.04792 \qquad H_2(S) = 0.1663$$

$$G_3(S) = 0.05864 \qquad H_3(S) = S$$

$$G_4(S) = 1.0 \qquad H_4(S) = 0.15\left[\frac{1}{S + 1}\right]$$

$$G_5(S) = -24.64\left[\frac{S^2 + 1.25 + 5.367}{S^4 + 2.802S^3 + 15.19S^2 + 1.179S + 0.0224}\right]$$

The Laplace domain representation for δ_S as a function of time and $(\theta_c - \theta)$ becomes

$$(S^5 + 18.45S^4 + 35.57S^3 + 95.0S^2 + 1.201S + 0.0224)\,\delta_S(S) =$$
$$- 0.01113K_p(S^5 + 3.802S^4 + 17.99S^3 + 16.37S^2 + 1.201S$$
$$+ 0.0224)[\theta_c - \theta(S)].$$

The value of K_p, pilot force per radian of pitch angle error, was varied depending on what gain was required to achieve an average pitch rate of 0.115 radians per second which is equivalent to a change in normal acceleration from steady state conditions of 3g (typical in fact of the pitch rate a pilot would use in making a dive angle correction).

In addition, the pilot was assumed to be aware that actual flight path angle (dive angle) lagged the pitch attitude angle during a changing pitch rate by the amount of instantaneous angle of attack. Since the purpose was dive angle change not just pitch attitude change, $\theta-\alpha$ or γ was fed back in the control system to solve for δ_s as a function of time and $(\gamma_c-\gamma)$ rather than $(\theta_c-\theta)$. This is the representation shown in the matrix feedback differential equation of Figure 3.

The simplification of the transfer functions listed above necessitated using airframe dynamics alone, in a simulated stick fixed condition, rather than coupled with the control system after the desired dive angle was approached, since very small pitch rates were outside the limits for which the simplified forms of $G_2(S)$, $G_4(S)$ and $H_1(S)$ applied.

APPENDIX B: NUMERICAL VALUES OF CONTROL VECTOR AND ELEMENTS OF THE PLANT MATRIX FOR REFERENCE DIVE ANGLES USED

The elements of the control vector derived in Sections II-B and II-C are invariant with dive angle. Values of elements of the control vector are listed in Figure 8.

Derivation of formulae for the elements of the plant matrix is in Sections II-B and II-C, and the matrix is shown in symbol form in Figure 3. Definitions of the elements is in "Definitions of Symbols" at the front of this study. Calculation of the airframe dynamics entries was accomplished in the following manner:

1. Dimensionless stability axis data were obtained from References 1 and 2.

2. Dimensionless body axis figures were computed from the "Definitions of Symbols", using stability axis data and reference state angle of attack.

3. Dimensional body axis figures were calculated using dimensionless body axis figures, dimensional derivative definitions, and applicable reference state data. Tables III and IV are compilations of the unperturbed 40° reference state conditions, and aerodynamic coefficients/stability derivatives for each reference dive angle used. Figure 8 lists the values of the plant matrix elements for each dive angle.

Since the aircraft was assumed in a constant speed (except for perturbations) 500 knot dive, rather than accelerating from 430 KTAS to 500 KTAS, lift and drag coefficients from References 1 and 2 were invalid. These coefficients were calculated for each dive angle from free body force balance diagrams.

Table III. 40° Dive Reference Conditions and Stability Axis Aerodynamics Coefficients and Stability Derivatives

$\Gamma_0 = -40° = -0.6981$ radians

$V_{T_0} = 844.4$ ft/sec

$U_0 = 844.4$ ft/sec

$W_0 = 3.369$ ft/sec

$M_0 = .775$

$\Theta_0 = -39.77° = -0.6941$ radians

$\alpha_0 = 3.99$ mils $= 0.2286° = 0.00399$ radians

$m = 1210$ slugs

$W = 38920$ lb

$\rho = 0.001933$ slugs/ft^3

$S = 530$ ft^2

$\bar{c} = 16.04$ ft

$\bar{q} = 689.1$ lb/ft^2

$g = 32.17$ ft/sec^2

$I_y = 122200$ slug ft^2

$\xi_0 = 5.25°$

$l_{th} = -0.57$ ft

$l_B = 39.4$ ft

$C_D = 0.06535$

$C_{D\alpha} = 0.1464$

$C_{DM} = 0$

$C_{D\delta_S} = 0$

$C_L = 0.1391$

$C_{L\alpha} = 3.36$

$C_{L\dot{\alpha}} = 0.7$

$C_{LM} = 0$

$C_{Lq} = 2.22$

$C_{L\delta_S} = 0.355$

$C_m = 0$

$C_{m\alpha} = -0.287$

$C_{m\dot{\alpha}} = -1.0$

$C_{mM} = -0.0314$

$C_{mq} = -2.37$

$C_{m\delta_S} = -0.515$

Table IV. Body Axis Force Coefficients and Stability Derivatives.

Γ	-32°	-35°	-40°	-45°	-48°
C_X	0.05026	0.0611	0.06479	0.07144	0.07717
$C_{X\alpha}$	-0.002913	-0.002064	-0.006367	-0.006422	-0.01468
C_{XM}	0	0	0	0	0
$C_{X\delta_S}$	-0.001416	-0.001416	-0.001416	-0.001416	-0.001416
C_N	0.1259	0.1317	0.1394	0.1495	0.1628
$C_{N\alpha}$	3.411	3.422	3.425	3.432	3.437
$C_{N\dot{\alpha}}$	0.7	0.7	0.7	0.7	0.7
C_{NM}	0	0	0	0	0
C_{Nq}	2.22	2.22	2.22	2.22	2.22
$C_{N\delta_S}$	0.355	0.355	0.355	0.355	0.355
X_u	-0.03541	-0.04345	-0.04633	-0.05129	-0.05566
X_α	0.6541	0.4344	1.766	1.911	4.534
X_q	-0.0254	-0.0254	-0.0254	-0.0254	-0.0254
$X\delta_S$	0.4274	0.4274	0.4274	0.4274	0.4274
Z_u	-0.08029	-0.08759	-0.09478	-0.1061	-0.118
Z_α	- 1010.	- 1022.	- 1034.	- 1045.	- 1056.
$Z_{\dot{\alpha}}$	-2.007	-2.007	-2.007	-2.007	-2.007
Z_q	-6.365	-6.365	-6.365	-6.365	-6.365
$Z\delta_S$	-107.2	-107.2	-107.2	-107.2	-107.2
M_u	-0.001317	-0.001317	-0.001317	-0.001317	-0.001317
M_α	-13.76	-13.76	-13.76	-13.76	-13.76
$M_{\dot{\alpha}}$	-0.4553	-0.4553	-0.4553	-0.4553	-0.4553
M_q	-1.079	-1.079	-1.079	-1.079	-1.079

$M\delta_S$	-24.69	-24.69	-24.69	-24.69	-24.69
$\frac{\partial T}{\partial M}$	0	0	0	0	0
T_u	0	0	0	0	0

PLANT MATRICES FOR EACH REFERENCE DIVE ANGLE AND THE CONTROL VECTOR

THE PLANT MATRIX FOR PERTURBATIONS FROM A 32 DEGREE DIVE:
REDUCED MATRIX FOR AIRCRAFT DYNAMICS ONLY IS ENCLOSED.

$$\begin{bmatrix} -.03541 & 0.6541 & -27.97 & -5.862 & 0.4274 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.00009581 & -1.205 & 0.01896 & 0.99 & -0.1267 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.001273 & -13.21 & -0.008633 & -1.53 & -24.63 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & -0.0224 & -1.201 & -95.0 & -35.57 & -18.45 \end{bmatrix}$$

THE PLANT MATRIX FOR PERTURBATIONS FROM A 35 DEGREE DIVE:
REDUCED MATRIX FOR AIRCRAFT DYNAMICS ONLY IS ENCLOSED.

$$\begin{bmatrix} -0.04345 & 0.4344 & -26.26 & -4.189 & 0.4274 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.000104 & -1.214 & 0.02207 & 0.9901 & -0.1267 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.00127 & -13.21 & -0.011005 & -1.53 & -24.63 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & -0.0224 & -1.201 & -95.0 & -35.57 & -18.45 \end{bmatrix}$$

THE PLANT MATRIX FOR PERTURBATIONS FROM A 40 DEGREE DIVE:
REDUCED MATRIX FOR AIRCRAFT DYNAMICS ONLY IS ENCLOSED.

$$\begin{bmatrix} -0.04633 & 1.766 & -24.73 & -3.394 & 0.4274 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.000112 & -1.222 & 0.02431 & 0.9901 & -0.1267 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.001266 & -13.2 & -0.01107 & -1.53 & -24.63 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & -0.0224 & -1.201 & -95.0 & -35.57 & -18.45 \end{bmatrix}$$

FIGURE 8

THE PLANT MATRIX FOR PERTURBATIONS FROM A 45 DEGREE DIVE:
REDUCED MATRIX FOR AIRCRAFT DYNAMICS ONLY IS ENCLOSED.

$$\begin{bmatrix} -0.5129 & 1.911 & -22.77 & -0.8711 & 0.4274 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.0001248 & -1.229 & 0.02433 & 0.9902 & -0.1267 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.00126 & -13.2 & -0.01108 & -1.53 & -24.63 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & -0.0224 & -1.201 & -95.0 & -35.57 & -18.45 \end{bmatrix}$$

THE PLANT MATRIX FOR PERTURBATIONS FROM A 48 DEGREE DIVE:
REDUCED MATRIX FOR AIRCRAFT DYNAMICS ONLY IS ENCLOSED.

$$\begin{bmatrix} -0.5566 & 4.534 & -20.67 & 0.4006 & 0.4274 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.0001382 & -1.237 & 0.02887 & 0.9902 & -0.1267 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 \\ -0.001254 & -13.2 & -0.01314 & 1.53 & -24.63 & 0.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 & 0.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 0.0 & 1.0 \\ 0.0 & 0.0 & 0.0 & 0.0 & -0.0224 & -1.201 & -95.0 & -35.57 & -18.45 \end{bmatrix}$$

ELEMENTS OF THE CONTROL VECTOR, APPLICABLE TO ALL DIVE ANGLES

$$\begin{bmatrix} -0.00483 & 0.001431 & 0.0 & 0.2783 & 0.1655 & -2.856 & 47.67 & -793.8 & 13200.0 \end{bmatrix}$$

FIGURE 8 (CONT.)

COMPUTER OUTPUT

RUN 1, 2.2 DEGREES SHALLOW, 5 DEGREE CORRECTION

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PULL UP FROM 40 TO 35 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
0.0	0.0	0.0	0.0	0.0	0.0
2.500E-02	-6.147E-04	-8.199E-03	2.284E-03	1.669E-03	1.252E-01
5.000E-02	-9.135E-04	-2.625E-02	6.835E-03	5.921E-03	2.094E-01
7.500E-02	-9.147E-04	-5.272E-02	1.282E-02	1.191E-02	2.656E-01
1.000E-01	-6.327E-04	-8.659E-02	1.967E-02	1.904E-02	3.026E-01
1.250E-01	-7.987E-05	-1.271E-01	2.701E-02	2.693E-02	3.263E-01
1.500E-01	7.328E-04	-1.738E-01	3.454E-02	3.528E-02	3.405E-01
1.750E-01	1.794E-03	-2.262E-01	4.210E-02	4.389E-02	3.478E-01
2.000E-01	3.094E-03	-2.838E-01	4.953E-02	5.262E-02	3.499E-01
2.250E-01	4.619E-03	-3.465E-01	5.673E-02	6.135E-02	3.480E-01
2.500E-01	6.359E-03	-4.138E-01	6.364E-02	7.000E-02	3.430E-01
2.750E-01	8.301E-03	-4.855E-01	7.018E-02	7.848E-02	3.354E-01
3.000E-01	1.043E-02	-5.613E-01	7.632E-02	8.675E-02	3.257E-01
3.250E-01	1.273E-02	-6.409E-01	8.202E-02	9.475E-02	3.142E-01
3.500E-01	1.520E-02	-7.239E-01	8.725E-02	1.024E-01	3.012E-01
3.750E-01	1.781E-02	-8.101E-01	9.199E-02	1.098E-01	2.869E-01
4.000E-01	2.055E-02	-8.992E-01	9.623E-02	1.168E-01	2.714E-01
4.250E-01	2.340E-02	-9.908E-01	9.996E-02	1.234E-01	2.551E-01
4.500E-01	2.635E-02	-1.085E 00	1.032E-01	1.295E-01	2.381E-01
4.750E-01	2.939E-02	-1.181E 00	1.059E-01	1.353E-01	2.205E-01
5.000E-01	3.249E-02	-1.278E 00	1.081E-01	1.405E-01	2.025E-01
5.250E-01	3.565E-02	-1.377E 00	1.097E-01	1.454E-01	1.842E-01
5.500E-01	3.884E-02	-1.477E 00	1.109E-01	1.498E-01	1.659E-01
5.750E-01	4.206E-02	-1.578E 00	1.116E-01	1.537E-01	1.476E-01
6.000E-01	4.529E-02	-1.679E 00	1.119E-01	1.571E-01	1.295E-01
6.250E-01	4.851E-02	-1.781E 00	1.116E-01	1.602E-01	1.118E-01
6.500E-01	5.171E-02	-1.883E 00	1.110E-01	1.627E-01	9.461E-02
6.750E-01	5.489E-02	-1.985E 00	1.100E-01	1.649E-01	7.800E-02
7.000E-01	5.802E-02	-2.087E 00	1.086E-01	1.666E-01	6.212E-02
7.250E-01	6.110E-02	-2.188E 00	1.069E-01	1.680E-01	4.709E-02
7.500E-01	6.412E-02	-2.289E 00	1.049E-01	1.690E-01	3.301E-02
7.750E-01	6.708E-02	-2.389E 00	1.026E-01	1.697E-01	1.998E-02
8.000E-01	6.995E-02	-2.488E 00	1.001E-01	1.700E-01	8.080E-03

8.250E-01	7.275E-02	-2.586E 00	9.733E-02	1.701E-01	-2.601E-03
8.500E-01	7.545E-02	-2.684E 00	9.444E-02	1.699E-01	-1.200E-02
8.750E-01	7.806E-02	-2.781E 00	9.142E-02	1.695E-01	-2.007E-02
9.000E-01	8.058E-02	-2.876E 00	8.832E-02	1.689E-01	-2.674E-02
9.250E-01	8.300E-02	-2.971E 00	8.517E-02	1.682E-01	-3.200E-02
9.500E-01	8.531E-02	-3.065E 00	8.199E-02	1.673E-01	-3.582E-02
9.750E-01	8.754E-02	-3.158E 00	7.885E-02	1.664E-01	-3.817E-02

TIME RESPONSE OF PERTURBATION QUANTITIES DURING 35 DEGREE DIVE

TIME	GAMMA	U	ALPHA	THETA	Q
9.750E-01	3.500E-04	0.0	7.785E-02	7.820E-02	-3.817E-02
1.050E 00	6.751E-03	-1.245E-01	6.609E-02	7.284E-02	-1.016E-01
1.125E 00	1.191E-02	-2.174E-01	5.153E-02	6.344E-02	-1.457E-01
1.200E 00	1.568E-02	-2.784E-01	3.579E-02	5.146E-02	-1.707E-01
1.275E 00	1.801E-02	-3.098E-01	2.026E-02	3.828E-02	-1.782E-01
1.350E 00	1.901E-02	-3.154E-01	6.086E-03	2.510E-02	-1.710E-01
1.425E 00	1.885E-02	-3.006E-01	-5.926E-03	1.292E-02	-1.522E-01
1.500E 00	1.774E-02	-2.711E-01	-1.527E-02	2.472E-03	-1.254E-01
1.575E 00	1.596E-02	-2.327E-01	-2.174E-02	-5.782E-03	-9.421E-02
1.650E 00	1.375E-02	-1.907E-01	-2.537E-02	-1.163E-02	-6.167E-02
1.725E 00	1.136E-02	-1.499E-01	-2.642E-02	-1.507E-02	-3.053E-02
1.800E 00	9.000E-03	-1.140E-01	-2.529E-02	-1.629E-02	-2.847E-03
1.875E 00	6.848E-03	-8.559E-02	-2.247E-02	-1.562E-02	1.992E-02
1.950E 00	5.022E-03	-6.627E-02	-1.847E-02	-1.345E-02	3.697E-02
2.025E 00	3.600E-03	-5.667E-02	-1.382E-02	-1.022E-02	4.808E-02
2.100E 00	2.613E-03	-5.654E-02	-8.992E-03	-6.378E-03	5.351E-02
2.175E 00	2.055E-03	-6.499E-02	-4.376E-03	-2.321E-03	5.390E-02
2.250E 00	1.886E-03	-8.061E-02	-2.827E-04	1.604E-03	5.016E-02
2.325E 00	2.048E-03	-1.017E-01	3.077E-03	5.125E-03	4.333E-02
2.400E 00	2.466E-03	-1.266E-01	5.586E-03	8.052E-03	3.449E-02
2.475E 00	3.061E-03	-1.534E-01	7.213E-03	1.027E-02	2.468E-02
2.550E 00	3.755E-03	-1.806E-01	7.999E-03	1.175E-02	1.483E-02
2.625E 00	4.476E-03	-2.069E-01	8.040E-03	1.252E-02	5.667E-03
2.700E 00	5.165E-03	-2.313E-01	7.470E-03	1.264E-02	-2.232E-03
2.775E 00	5.774E-03	-2.531E-01	6.447E-03	1.222E-02	-8.510E-03
2.850E 00	6.273E-03	-2.719E-01	5.130E-03	1.140E-02	-1.300E-02
2.925E 00	6.644E-03	-2.878E-01	3.673E-03	1.032E-02	-1.568E-02
3.000E 00	6.881E-03	-3.007E-01	2.212E-03	9.093E-03	-1.670E-02
3.075E 00	6.991E-03	-3.111E-01	8.576E-04	7.848E-03	-1.628E-02
3.150E 00	6.988E-03	-3.195E-01	-3.083E-04	6.680E-03	-1.472E-02
3.225E 00	6.893E-03	-3.263E-01	-1.233E-03	5.660E-03	-1.235E-02
3.300E 00	6.729E-03	-3.321E-01	-1.890E-03	4.839E-03	-9.497E-03
3.375E 00	6.521E-03	-3.375E-01	-2.281E-03	4.240E-03	-6.465E-03
3.450E 00	6.292E-03	-3.429E-01	-2.425E-03	3.867E-03	-3.514E-03
3.525E 00	6.063E-03	-3.486E-01	-2.357E-03	3.706E-03	-8.523E-04
3.600E 00	5.849E-03	-3.549E-01	-2.121E-03	3.728E-03	1.374E-03
3.675E 00	5.664E-03	-3.620E-01	-1.765E-03	3.899E-03	3.077E-03
3.750E 00	5.516E-03	-3.699E-01	-1.339E-03	4.176E-03	4.227E-03
3.825E 00	5.407E-03	-3.787E-01	-8.882E-04	4.519E-03	4.838E-03
3.900E 00	5.340E-03	-3.883E-01	-4.500E-04	4.890E-03	4.965E-03

3.975E 00	5.309E-03	-3.986E-01	-5.536E-05	5.254E-03	4.687E-03
4.050E 00	5.311E-03	-4.093E-01	2.741E-04	5.585E-03	4.100E-03
4.125E 00	5.338E-03	-4.204E-01	5.257E-04	5.864E-03	3.306E-03
4.200E 00	5.383E-03	-4.317E-01	6.951E-04	6.078E-03	2.402E-03
4.275E 00	5.439E-03	-4.429E-01	7.847E-04	6.223E-03	1.478E-03
4.350E 00	5.498E-03	-4.541E-01	8.026E-04	6.301E-03	6.051E-04
4.425E 00	5.556E-03	-4.651E-01	7.608E-04	6.317E-03	-1.590E-04
4.500E 00	5.607E-03	-4.758E-01	6.736E-04	6.281E-03	-7.774E-04
4.575E 00	5.648E-03	-4.862E-01	5.559E-04	6.204E-03	-1.230E-03
4.650E 00	5.678E-03	-4.963E-01	4.224E-04	6.100E-03	-1.515E-03
4.725E 00	5.695E-03	-5.060E-01	2.860E-04	5.981E-03	-1.640E-03
4.800E 00	5.700E-03	-5.155E-01	1.577E-04	5.858E-03	-1.626E-03
4.875E 00	5.694E-03	-5.247E-01	4.560E-05	5.740E-03	-1.499E-03
4.950E 00	5.680E-03	-5.338E-01	-4.473E-05	5.635E-03	-1.291E-03
5.025E 00	5.658E-03	-5.426E-01	-1.105E-04	5.548E-03	-1.031E-03
5.100E 00	5.632E-03	-5.514E-01	-1.512E-04	5.481E-03	-7.495E-04
5.175E 00	5.603E-03	-5.602E-01	-1.683E-04	5.435E-03	-4.707E-04
5.250E 00	5.574E-03	-5.689E-01	-1.649E-04	5.410E-03	-2.154E-04
5.325E 00	5.547E-03	-5.777E-01	-1.449E-04	5.402E-03	1.663E-06
5.400E 00	5.521E-03	-5.865E-01	-1.129E-04	5.409E-03	1.711E-04
5.475E 00	5.499E-03	-5.953E-01	-7.338E-05	5.426E-03	2.892E-04
5.550E 00	5.481E-03	-6.041E-01	-3.069E-05	5.451E-03	3.563E-04
5.625E 00	5.467E-03	-6.130E-01	1.146E-05	5.478E-03	3.770E-04
5.700E 00	5.456E-03	-6.219E-01	5.005E-05	5.506E-03	3.583E-04
5.775E 00	5.448E-03	-6.309E-01	8.290E-05	5.531E-03	3.089E-04
5.850E 00	5.443E-03	-6.398E-01	1.087E-04	5.552E-03	2.382E-04
5.925E 00	5.440E-03	-6.487E-01	1.268E-04	5.567E-03	1.554E-04
6.000E 00	5.438E-03	-6.576E-01	1.373E-04	5.575E-03	6.910E-05
6.075E 00	5.436E-03	-6.664E-01	1.410E-04	5.577E-03	-1.360E-05
6.150E 00	5.434E-03	-6.752E-01	1.389E-04	5.573E-03	-8.713E-05
6.225E 00	5.432E-03	-6.839E-01	1.322E-04	5.564E-03	-1.476E-04
6.300E 00	5.429E-03	-6.926E-01	1.225E-04	5.551E-03	-1.929E-04
6.375E 00	5.425E-03	-7.011E-01	1.109E-04	5.536E-03	-2.225E-04
6.450E 00	5.420E-03	-7.096E-01	9.887E-05	5.518E-03	-2.369E-04
6.525E 00	5.413E-03	-7.181E-01	8.739E-05	5.501E-03	-2.379E-04
6.600E 00	5.406E-03	-7.265E-01	7.728E-05	5.483E-03	-2.278E-04
6.675E 00	5.397E-03	-7.348E-01	6.911E-05	5.467E-03	-2.095E-04
6.750E 00	5.388E-03	-7.431E-01	6.320E-05	5.452E-03	-1.859E-04
6.825E 00	5.379E-03	-7.513E-01	5.963E-05	5.439E-03	-1.596E-04
6.900E 00	5.369E-03	-7.595E-01	5.829E-05	5.428E-03	-1.332E-04
6.975E 00	5.360E-03	-7.677E-01	5.894E-05	5.419E-03	-1.087E-04
7.050E 00	5.350E-03	-7.758E-01	6.121E-05	5.411E-03	-8.742E-05
7.125E 00	5.341E-03	-7.839E-01	6.468E-05	5.405E-03	-7.048E-05
7.200E 00	5.332E-03	-7.919E-01	6.894E-05	5.401E-03	-5.831E-05

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PUSH OVER FROM 35 TO 40 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
7.200E 00	5.300E-03	-8.238E-01	8.463E-05	5.385E-03	-5.281E-05
7.225E 00	5.942E-03	-8.165E-01	-2.277E-03	3.666E-03	-1.312E-01
7.250E 00	6.263E-03	-7.963E-01	-7.074E-03	-8.116E-04	-2.210E-01
7.275E 00	6.268E-03	-7.653E-01	-1.340E-02	-7.137E-03	-2.810E-01
7.300E 00	5.973E-03	-7.249E-01	-2.066E-02	-1.469E-02	-3.205E-01
7.325E 00	5.392E-03	-6.763E-01	-2.844E-02	-2.305E-02	-3.458E-01
7.350E 00	4.537E-03	-6.201E-01	-3.644E-02	-3.190E-02	-3.610E-01
7.375E 00	3.418E-03	-5.571E-01	-4.445E-02	-4.104E-02	-3.688E-01
7.400E 00	2.047E-03	-4.877E-01	-5.234E-02	-5.030E-02	-3.712E-01
7.425E 00	4.375E-04	-4.125E-01	-6.000E-02	-5.956E-02	-3.692E-01
7.450E 00	-1.399E-03	-3.317E-01	-6.733E-02	-6.873E-02	-3.640E-01
7.475E 00	-3.449E-03	-2.458E-01	-7.428E-02	-7.773E-02	-3.560E-01
7.500E 00	-5.698E-03	-1.553E-01	-8.081E-02	-8.651E-02	-3.457E-01
7.525E 00	-8.131E-03	-6.039E-02	-8.687E-02	-9.500E-02	-3.335E-01
7.550E 00	-1.073E-02	3.843E-02	-9.244E-02	-1.032E-01	-3.197E-01
7.575E 00	-1.349E-02	1.408E-01	-9.749E-02	-1.110E-01	-3.046E-01
7.600E 00	-1.639E-02	2.464E-01	-1.020E-01	-1.184E-01	-2.882E-01
7.625E 00	-1.940E-02	3.547E-01	-1.060E-01	-1.254E-01	-2.709E-01
7.650E 00	-2.252E-02	4.655E-01	-1.094E-01	-1.319E-01	-2.529E-01
7.675E 00	-2.573E-02	5.783E-01	-1.123E-01	-1.380E-01	-2.342E-01
7.700E 00	-2.901E-02	6.929E-01	-1.146E-01	-1.436E-01	-2.151E-01
7.725E 00	-3.235E-02	8.088E-01	-1.164E-01	-1.488E-01	-1.957E-01
7.750E 00	-3.573E-02	9.257E-01	-1.177E-01	-1.534E-01	-1.763E-01
7.775E 00	-3.914E-02	1.043E 00	-1.184E-01	-1.576E-01	-1.569E-01
7.800E 00	-4.255E-02	1.161E 00	-1.187E-01	-1.613E-01	-1.377E-01
7.825E 00	-4.596E-02	1.280E 00	-1.185E-01	-1.645E-01	-1.189E-01
7.850E 00	-4.935E-02	1.398E 00	-1.179E-01	-1.672E-01	-1.006E-01
7.875E 00	-5.271E-02	1.515E 00	-1.168E-01	-1.695E-01	-8.298E-02
7.900E 00	-5.603E-02	1.633E 00	-1.153E-01	-1.714E-01	-6.610E-02
7.925E 00	-5.930E-02	1.749E 00	-1.135E-01	-1.728E-01	-5.012E-02
7.950E 00	-6.250E-02	1.865E 00	-1.114E-01	-1.739E-01	-3.515E-02
7.975E 00	-6.563E-02	1.979E 00	-1.090E-01	-1.746E-01	-2.128E-02
8.000E 00	-6.868E-02	2.092E 00	-1.063E-01	-1.750E-01	-8.617E-03
8.025E 00	-7.164E-02	2.204E 00	-1.034E-01	-1.750E-01	2.764E-03
8.050E 00	-7.450E-02	2.315E 00	-1.003E-01	-1.748E-01	1.279E-02
8.075E 00	-7.727E-02	2.425E 00	-9.712E-02	-1.744E-01	2.140E-02
8.100E 00	-7.994E-02	2.533E 00	-9.383E-02	-1.738E-01	2.854E-02
8.124E 00	-8.251E-02	2.640E 00	-9.047E-02	-1.730E-01	3.418E-02
8.149E 00	-8.497E-02	2.746E 00	-8.710E-02	-1.721E-01	3.830E-02
8.174E 00	-8.733E-02	2.851E 00	-8.375E-02	-1.711E-01	4.086E-02

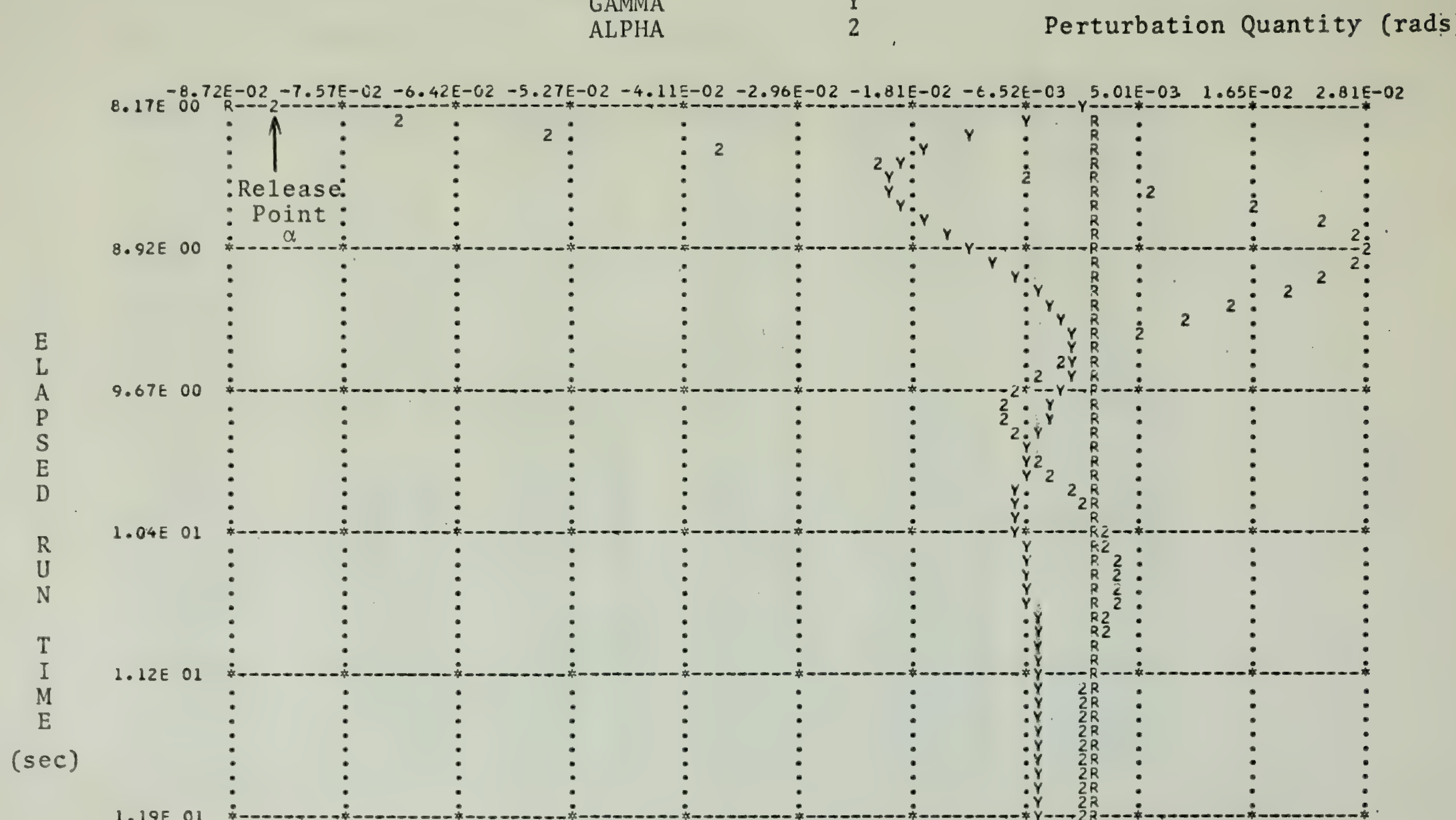
TIME RESPONSE OF PERTURBATION QUANTITIES DURING 40 DEGREE DIVE

TIME	GAMMA	U	ALPHA	THETA	Q
8.175E 00	-2.200E-04	-3.460E-01	-8.278E-02	-8.300E-02	4.049E-02
8.250E 00	-7.061E-03	-2.251E-01	-7.025E-02	-7.731E-02	1.079E-01
8.325E 00	-1.258E-02	-1.320E-01	-5.475E-02	-6.732E-02	1.548E-01
8.400E 00	-1.659E-02	-6.759E-02	-3.801E-02	-5.460E-02	1.813E-01
8.475E 00	-1.909E-02	-3.053E-02	-2.150E-02	-4.059E-02	1.893E-01
8.550E 00	-2.015E-02	-1.758E-02	-6.439E-03	-2.659E-02	1.816E-01
8.625E 00	-1.997E-02	-2.431E-02	6.320E-03	-1.365E-02	1.617E-01
8.700E 00	-1.879E-02	-4.564E-02	1.624E-02	-2.553E-03	1.333E-01
8.775E 00	-1.688E-02	-7.635E-02	2.310E-02	6.219E-03	1.001E-01
8.850E 00	-1.452E-02	-1.115E-01	2.696E-02	1.243E-02	6.561E-02
8.925E 00	-1.197E-02	-1.466E-01	2.807E-02	1.610E-02	3.255E-02
9.000E 00	-9.461E-03	-1.783E-01	2.687E-02	1.741E-02	3.180E-03
9.075E 00	-7.164E-03	-2.037E-01	2.387E-02	1.671E-02	-2.098E-02
9.150E 00	-5.216E-03	-2.214E-01	1.963E-02	1.441E-02	-3.908E-02
9.225E 00	-3.699E-03	-2.305E-01	1.470E-02	1.100E-02	-5.088E-02
9.300E 00	-2.645E-03	-2.309E-01	9.578E-03	6.933E-03	-5.665E-02
9.375E 00	-2.048E-03	-2.235E-01	4.685E-03	2.637E-03	-5.709E-02
9.450E 00	-1.866E-03	-2.093E-01	3.462E-04	-1.520E-03	-5.314E-02
9.525E 00	-2.037E-03	-1.898E-01	-3.215E-03	-5.252E-03	-4.592E-02
9.600E 00	-2.480E-03	-1.665E-01	-5.875E-03	-8.355E-03	-3.657E-02
9.675E 00	-3.112E-03	-1.411E-01	-7.600E-03	-1.071E-02	-2.620E-02
9.750E 00	-3.849E-03	-1.149E-01	-8.434E-03	-1.228E-02	-1.576E-02
9.825E 00	-4.615E-03	-8.930E-02	-8.480E-03	-1.309E-02	-6.069E-03
9.900E 00	-5.347E-03	-6.517E-02	-7.880E-03	-1.323E-02	2.296E-03
9.975E 00	-5.995E-03	-4.322E-02	-6.799E-03	-1.279E-02	8.948E-03
1.005E 01	-6.525E-03	-2.385E-02	-5.407E-03	-1.193E-02	1.370E-02
1.012E 01	-6.919E-03	-7.207E-03	-3.867E-03	-1.079E-02	1.656E-02
1.020E 01	-7.170E-03	6.814E-03	-2.322E-03	-9.493E-03	1.765E-02
1.027E 01	-7.287E-03	1.847E-02	-8.896E-04	-8.177E-03	1.722E-02
1.035E 01	-7.284E-03	2.816E-02	3.437E-04	-6.940E-03	1.558E-02
1.042E 01	-7.183E-03	3.634E-02	1.322E-03	-5.861E-03	1.308E-02
1.050E 01	-7.009E-03	4.350E-02	2.018E-03	-4.991E-03	1.007E-02
1.057E 01	-6.788E-03	5.011E-02	2.433E-03	-4.355E-03	6.875E-03
1.065E 01	-6.544E-03	5.658E-02	2.587E-03	-3.957E-03	3.760E-03
1.072E 01	-6.299E-03	6.327E-02	2.516E-03	-3.783E-03	9.489E-04
1.080E 01	-6.072E-03	7.043E-02	2.268E-03	-3.803E-03	-1.404E-03
1.087E 01	-5.874E-03	7.825E-02	1.894E-03	-3.980E-03	-3.207E-03
1.095E 01	-5.715E-03	8.680E-02	1.446E-03	-4.270E-03	-4.425E-03
1.102E 01	-5.599E-03	9.611E-02	9.700E-04	-4.629E-03	-5.076E-03
1.110E 01	-5.526E-03	1.061E-01	5.078E-04	-5.018E-03	-5.215E-03

1.117E 01	-5.492E-03	1.167E-01	9.142E-05	-5.401E-03	-4.928E-03
1.125E 01	-5.493E-03	1.278E-01	-2.564E-04	-5.749E-03	-4.314E-03
1.132E 01	-5.520E-03	1.393E-01	-5.224E-04	-6.042E-03	-3.480E-03
1.140E 01	-5.567E-03	1.509E-01	-7.017E-04	-6.268E-03	-2.530E-03
1.147E 01	-5.624E-03	1.625E-01	-7.969E-04	-6.421E-03	-1.557E-03
1.155E 01	-5.687E-03	1.741E-01	-8.166E-04	-6.503E-03	-6.382E-04
1.162E 01	-5.747E-03	1.855E-01	-7.734E-04	-6.520E-03	1.675E-04
1.170E 01	-5.800E-03	1.967E-01	-6.821E-04	-6.482E-03	8.203E-04
1.177E 01	-5.843E-03	2.076E-01	-5.587E-04	-6.401E-03	1.299E-03
1.185E 01	-5.873E-03	2.182E-01	-4.185E-04	-6.291E-03	1.601E-03
1.192E 01	-5.890E-03	2.285E-01	-2.751E-04	-6.165E-03	1.735E-03

GRAPHICAL TIME RESPONSE OF PERTURBATION GAMMA AND ALPHA AFTER RE-ESTABLISHMENT IN DESIRED 40° DIVE

VARIABLE	SYMBOL
GAMMA COMMAND	R
GAMMA	Y
ALPHA	2



RUN 2, 2.2 DEGREES SHALLOW, 8 DEGREE CORRECTION

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PULL UP FROM 40 TO 32 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
0.0	0.0	0.0	0.0	0.0	0.0
2.500E-02	-6.285E-04	-8.386E-03	2.336E-03	1.707E-03	1.281E-01
5.000E-02	-9.328E-04	-2.684E-02	6.986E-03	6.053E-03	2.138E-01
7.500E-02	-9.331E-04	-5.386E-02	1.310E-02	1.216E-02	2.711E-01
1.000E-01	-6.450E-04	-8.843E-02	2.009E-02	1.945E-02	3.089E-01
1.250E-01	-8.154E-05	-1.298E-01	2.758E-02	2.750E-02	3.333E-01
1.500E-01	7.458E-04	-1.775E-01	3.529E-02	3.603E-02	3.483E-01
1.750E-01	1.826E-03	-2.311E-01	4.303E-02	4.485E-02	3.565E-01
2.000E-01	3.149E-03	-2.902E-01	5.067E-02	5.382E-02	3.599E-01
2.250E-01	4.703E-03	-3.546E-01	5.811E-02	6.282E-02	3.595E-01
2.500E-01	6.477E-03	-4.239E-01	6.529E-02	7.177E-02	3.563E-01
2.750E-01	8.459E-03	-4.980E-01	7.215E-02	8.061E-02	3.508E-01
3.000E-01	1.064E-02	-5.766E-01	7.865E-02	8.929E-02	3.434E-01
3.250E-01	1.300E-02	-6.594E-01	8.477E-02	9.777E-02	3.345E-01
3.500E-01	1.554E-02	-7.462E-01	9.047E-02	1.060E-01	3.243E-01
3.750E-01	1.823E-02	-8.368E-01	9.575E-02	1.140E-01	3.131E-01
4.000E-01	2.107E-02	-9.309E-01	1.006E-01	1.217E-01	3.009E-01
4.250E-01	2.404E-02	-1.028E 00	1.050E-01	1.290E-01	2.880E-01
4.500E-01	2.712E-02	-1.129E 00	1.089E-01	1.360E-01	2.745E-01
4.750E-01	3.031E-02	-1.232E 00	1.124E-01	1.427E-01	2.605E-01
5.000E-01	3.360E-02	-1.338E 00	1.155E-01	1.491E-01	2.462E-01
5.250E-01	3.696E-02	-1.446E 00	1.181E-01	1.550E-01	2.317E-01
5.500E-01	4.038E-02	-1.556E 00	1.203E-01	1.607E-01	2.172E-01
5.750E-01	4.386E-02	-1.668E 00	1.220E-01	1.659E-01	2.026E-01
6.000E-01	4.738E-02	-1.782E 00	1.234E-01	1.708E-01	1.883E-01
6.250E-01	5.093E-02	-1.897E 00	1.244E-01	1.753E-01	1.741E-01
6.500E-01	5.449E-02	-2.014E 00	1.250E-01	1.795E-01	1.604E-01
6.750E-01	5.807E-02	-2.132E 00	1.253E-01	1.833E-01	1.471E-01
7.000E-01	6.163E-02	-2.251E 00	1.252E-01	1.869E-01	1.344E-01
7.250E-01	6.519E-02	-2.371E 00	1.249E-01	1.901E-01	1.224E-01
7.500E-01	6.873E-02	-2.491E 00	1.243E-01	1.930E-01	1.111E-01
7.750E-01	7.223E-02	-2.613E 00	1.234E-01	1.956E-01	1.006E-01
8.000E-01	7.571E-02	-2.734E 00	1.223E-01	1.980E-01	9.105E-02
8.250E-01	7.914E-02	-2.857E 00	1.210E-01	2.002E-01	8.244E-02
8.500E-01	8.252E-02	-2.980E 00	1.196E-01	2.021E-01	7.485E-02
8.750E-01	8.586E-02	-3.103E 00	1.181E-01	2.039E-01	6.833E-02
9.000E-01	8.914E-02	-3.227E 00	1.164E-01	2.056E-01	6.293E-02

9.250E-01	9.236E-02	-3.352E 00	1.147E-01	2.071E-01	5.868E-02
9.500E-01	9.553E-02	-3.477E 00	1.130E-01	2.085E-01	5.561E-02
9.750E-01	9.864E-02	-3.602E 00	1.112E-01	2.099E-01	5.374E-02
1.000E 00	1.017E-01	-3.728E 00	1.095E-01	2.112E-01	5.309E-02
1.025E 00	1.047E-01	-3.855E 00	1.079E-01	2.125E-01	5.366E-02
1.050E 00	1.076E-01	-3.983E 00	1.063E-01	2.139E-01	5.544E-02
1.075E 00	1.105E-01	-4.112E 00	1.048E-01	2.153E-01	5.844E-02
1.100E 00	1.134E-01	-4.242E 00	1.035E-01	2.168E-01	6.262E-02
1.125E 00	1.162E-01	-4.373E 00	1.023E-01	2.185E-01	6.798E-02
1.150E 00	1.189E-01	-4.506E 00	1.013E-01	2.202E-01	7.448E-02
1.175E 00	1.217E-01	-4.640E 00	1.005E-01	2.222E-01	8.208E-02
1.200E 00	1.244E-01	-4.777E 00	9.999E-02	2.244E-01	9.075E-02
1.225E 00	1.270E-01	-4.915E 00	9.970E-02	2.267E-01	1.004E-01

TIME RESPONSE OF PERTURBATION QUANTITIES DURING 32 DEGREE DIVE

TIME	GAMMA	U	ALPHA	THETA	Q
1.225E 00	-1.261E-02	0.0	9.671E-02	8.410E-02	1.004E-01
1.300E 00	-4.121E-03	-1.983E-01	9.191E-02	8.779E-02	6.960E-04
1.375E 00	3.578E-03	-3.569E-01	8.109E-02	8.466E-02	-8.067E-02
1.450E 00	1.005E-02	-4.722E-01	6.616E-02	7.622E-02	-1.410E-01
1.525E 00	1.504E-02	-5.443E-01	4.902E-02	6.406E-02	-1.795E-01
1.600E 00	1.844E-02	-5.769E-01	3.136E-02	4.980E-02	-1.975E-01
1.675E 00	2.030E-02	-5.756E-01	1.460E-02	3.489E-02	-1.973E-01
1.750E 00	2.074E-02	-5.478E-01	-1.651E-04	2.058E-02	-1.823E-01
1.825E 00	2.001E-02	-5.013E-01	-1.219E-02	7.822E-03	-1.564E-01
1.900E 00	1.837E-02	-4.441E-01	-2.108E-02	-2.704E-03	-1.235E-01
1.975E 00	1.612E-02	-3.833E-01	-2.674E-02	-1.062E-02	-8.738E-02
2.050E 00	1.352E-02	-3.251E-01	-2.934E-02	-1.581E-02	-5.137E-02
2.125E 00	1.085E-02	-2.742E-01	-2.925E-02	-1.840E-02	-1.816E-02
2.200E 00	8.322E-03	-2.342E-01	-2.698E-02	-1.866E-02	1.029E-02
2.275E 00	6.089E-03	-2.068E-01	-2.309E-02	-1.700E-02	3.271E-02
2.350E 00	4.270E-03	-1.928E-01	-1.819E-02	-1.392E-02	4.852E-02
2.425E 00	2.924E-03	-1.916E-01	-1.281E-02	-9.891E-03	5.776E-02
2.500E 00	2.063E-03	-2.018E-01	-7.467E-03	-5.404E-03	6.095E-02
2.575E 00	1.664E-03	-2.214E-01	-2.542E-03	-8.781E-04	5.896E-02
2.650E 00	1.669E-03	-2.482E-01	1.669E-03	3.338E-03	5.289E-02
2.725E 00	2.004E-03	-2.797E-01	4.980E-03	6.984E-03	4.396E-02
2.800E 00	2.582E-03	-3.135E-01	7.309E-03	9.891E-03	3.337E-02
2.875E 00	3.313E-03	-3.475E-01	8.662E-03	1.198E-02	2.221E-02
2.950E 00	4.115E-03	-3.801E-01	9.117E-03	1.323E-02	1.144E-02
3.025E 00	4.913E-03	-4.098E-01	8.807E-03	1.372E-02	1.787E-03
3.100E 00	5.647E-03	-4.360E-01	7.895E-03	1.354E-02	-6.225E-03
3.175E 00	6.274E-03	-4.580E-01	6.561E-03	1.283E-02	-1.230E-02
3.250E 00	6.765E-03	-4.760E-01	4.983E-03	1.175E-02	-1.633E-02
3.325E 00	7.108E-03	-4.901E-01	3.326E-03	1.043E-02	-1.840E-02
3.400E 00	7.304E-03	-5.008E-01	1.729E-03	9.033E-03	-1.871E-02
3.475E 00	7.365E-03	-5.089E-01	2.998E-04	7.665E-03	-1.756E-02
3.550E 00	7.310E-03	-5.150E-01	-8.838E-04	6.427E-03	-1.531E-02
3.625E 00	7.165E-03	-5.200E-01	-1.778E-03	5.387E-03	-1.233E-02
3.700E 00	6.957E-03	-5.244E-01	-2.370E-03	4.587E-03	-8.976E-03
3.775E 00	6.712E-03	-5.290E-01	-2.670E-03	4.042E-03	-5.575E-03
3.850E 00	6.454E-03	-5.341E-01	-2.709E-03	3.745E-03	-2.388E-03
3.925E 00	6.206E-03	-5.401E-01	-2.533E-03	3.673E-03	3.835E-04
4.000E 00	5.983E-03	-5.472E-01	-2.195E-03	3.789E-03	2.609E-03
4.075E 00	5.798E-03	-5.556E-01	-1.749E-03	4.049E-03	4.221E-03
4.150E 00	5.656E-03	-5.651E-01	-1.249E-03	4.406E-03	5.212E-03

4.225E 00	5.559E-03	-5.757E-01	-7.430E-04	4.816E-03	5.623E-03
4.300E 00	5.507E-03	-5.872E-01	-2.695E-04	5.237E-03	5.528E-03
4.375E 00	5.493E-03	-5.994E-01	1.419E-04	5.635E-03	5.029E-03
4.450E 00	5.513E-03	-6.120E-01	4.716E-04	5.984E-03	4.238E-03
4.525E 00	5.556E-03	-6.249E-01	7.101E-04	6.266E-03	3.268E-03
4.600E 00	5.616E-03	-6.377E-01	8.564E-04	6.473E-03	2.226E-03
4.675E 00	5.684E-03	-6.505E-01	9.165E-04	6.601E-03	1.202E-03
4.750E 00	5.753E-03	-6.629E-01	9.018E-04	6.655E-03	2.706E-04
4.825E 00	5.817E-03	-6.750E-01	8.275E-04	6.645E-03	-5.151E-04
4.900E 00	5.872E-03	-6.867E-01	7.101E-04	6.582E-03	-1.123E-03
4.975E 00	5.915E-03	-6.979E-01	5.664E-04	6.481E-03	-1.540E-03
5.050E 00	5.944E-03	-7.087E-01	4.123E-04	6.356E-03	-1.771E-03
5.125E 00	5.959E-03	-7.192E-01	2.613E-04	6.220E-03	-1.831E-03
5.200E 00	5.960E-03	-7.294E-01	1.243E-04	6.085E-03	-1.749E-03
5.275E 00	5.951E-03	-7.393E-01	8.973E-06	5.960E-03	-1.556E-03
5.350E 00	5.933E-03	-7.491E-01	-7.982E-05	5.853E-03	-1.288E-03

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PUSH OVER FROM 32 TO 40 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
5.350E 00	5.933E-03	-7.491E-01	-7.982E-05	5.853E-03	-1.288E-03
5.375E 00	6.572E-03	-7.395E-01	-2.476E-03	4.096E-03	-1.330E-01
5.400E 00	6.885E-03	-7.121E-01	-7.312E-03	-4.271E-04	-2.228E-01
5.425E 00	6.880E-03	-6.706E-01	-1.368E-02	-6.798E-03	-2.828E-01
5.450E 00	6.576E-03	-6.174E-01	-2.097E-02	-1.440E-02	-3.223E-01
5.475E 00	5.986E-03	-5.542E-01	-2.878E-02	-2.280E-02	-3.478E-01
5.500E 00	5.122E-03	-4.823E-01	-3.683E-02	-3.171E-02	-3.634E-01
5.525E 00	3.996E-03	-4.026E-01	-4.491E-02	-4.091E-02	-3.720E-01
5.550E 00	2.620E-03	-3.157E-01	-5.288E-02	-5.026E-02	-3.755E-01
5.575E 00	1.004E-03	-2.223E-01	-6.066E-02	-5.965E-02	-3.750E-01
5.600E 00	-8.401E-04	-1.229E-01	-6.815E-02	-6.899E-02	-3.716E-01
5.625E 00	-2.900E-03	-1.790E-02	-7.531E-02	-7.821E-02	-3.658E-01
5.650E 00	-5.162E-03	9.230E-02	-8.210E-02	-8.726E-02	-3.580E-01
5.675E 00	-7.615E-03	2.073E-01	-8.848E-02	-9.610E-02	-3.487E-01
5.700E 00	-1.025E-02	3.267E-01	-9.444E-02	-1.047E-01	-3.380E-01
5.725E 00	-1.304E-02	4.502E-01	-9.995E-02	-1.130E-01	-3.262E-01
5.750E 00	-1.598E-02	5.773E-01	-1.050E-01	-1.210E-01	-3.134E-01
5.775E 00	-1.906E-02	7.079E-01	-1.096E-01	-1.287E-01	-2.999E-01
5.800E 00	-2.227E-02	8.415E-01	-1.137E-01	-1.360E-01	-2.858E-01
5.825E 00	-2.558E-02	9.777E-01	-1.174E-01	-1.429E-01	-2.712E-01
5.850E 00	-2.898E-02	1.116E 00	-1.205E-01	-1.495E-01	-2.563E-01
5.875E 00	-3.247E-02	1.257E 00	-1.233E-01	-1.557E-01	-2.411E-01
5.900E 00	-3.602E-02	1.400E 00	-1.256E-01	-1.616E-01	-2.259E-01
5.925E 00	-3.963E-02	1.544E 00	-1.274E-01	-1.670E-01	-2.107E-01
5.950E 00	-4.328E-02	1.689E 00	-1.288E-01	-1.721E-01	-1.957E-01
5.975E 00	-4.696E-02	1.836E 00	-1.299E-01	-1.768E-01	-1.810E-01
6.000E 00	-5.066E-02	1.983E 00	-1.305E-01	-1.812E-01	-1.667E-01
6.025E 00	-5.436E-02	2.132E 00	-1.308E-01	-1.852E-01	-1.528E-01
6.050E 00	-5.807E-02	2.280E 00	-1.308E-01	-1.888E-01	-1.396E-01
6.075E 00	-6.176E-02	2.430E 00	-1.304E-01	-1.922E-01	-1.271E-01
6.100E 00	-6.543E-02	2.579E 00	-1.298E-01	-1.952E-01	-1.153E-01
6.125E 00	-6.907E-02	2.729E 00	-1.289E-01	-1.979E-01	-1.044E-01
6.150E 00	-7.267E-02	2.879E 00	-1.277E-01	-2.004E-01	-9.446E-02
6.175E 00	-7.623E-02	3.029E 00	-1.264E-01	-2.027E-01	-8.551E-02
6.200E 00	-7.975E-02	3.179E 00	-1.249E-01	-2.047E-01	-7.764E-02
6.225E 00	-8.321E-02	3.329E 00	-1.233E-01	-2.065E-01	-7.088E-02
6.250E 00	-8.662E-02	3.480E 00	-1.216E-01	-2.082E-01	-6.530E-02
6.274E 00	-8.997E-02	3.631E 00	-1.198E-01	-2.098E-01	-6.092E-02
6.299E 00	-9.327E-02	3.782E 00	-1.180E-01	-2.113E-01	-5.777E-02
6.324E 00	-9.650E-02	3.934E 00	-1.162E-01	-2.127E-01	-5.588E-02

6.349E 00	-9.967E-02	4.087E 00	-1.144E-01	-2.141E-01	-5.526E-02
6.374E 00	-1.028E-01	4.240E 00	-1.127E-01	-2.155E-01	-5.591E-02
6.399E 00	-1.059E-01	4.395E 00	-1.111E-01	-2.169E-01	-5.784E-02
6.424E 00	-1.089E-01	4.551E 00	-1.095E-01	-2.184E-01	-6.103E-02
6.449E 00	-1.118E-01	4.708E 00	-1.082E-01	-2.200E-01	-6.547E-02
6.474E 00	-1.147E-01	4.867E 00	-1.069E-01	-2.217E-01	-7.114E-02
6.499E 00	-1.176E-01	5.028E 00	-1.059E-01	-2.235E-01	-7.799E-02
6.524E 00	-1.205E-01	5.192E 00	-1.051E-01	-2.256E-01	-8.600E-02
6.549E 00	-1.233E-01	5.358E 00	-1.046E-01	-2.279E-01	-9.513E-02
6.574E 00	-1.261E-01	5.527E 00	-1.043E-01	-2.304E-01	-1.053E-01

TIME RESPONSE OF PERTURBATION QUANTITIES DURING 40 DEGREE DIVE

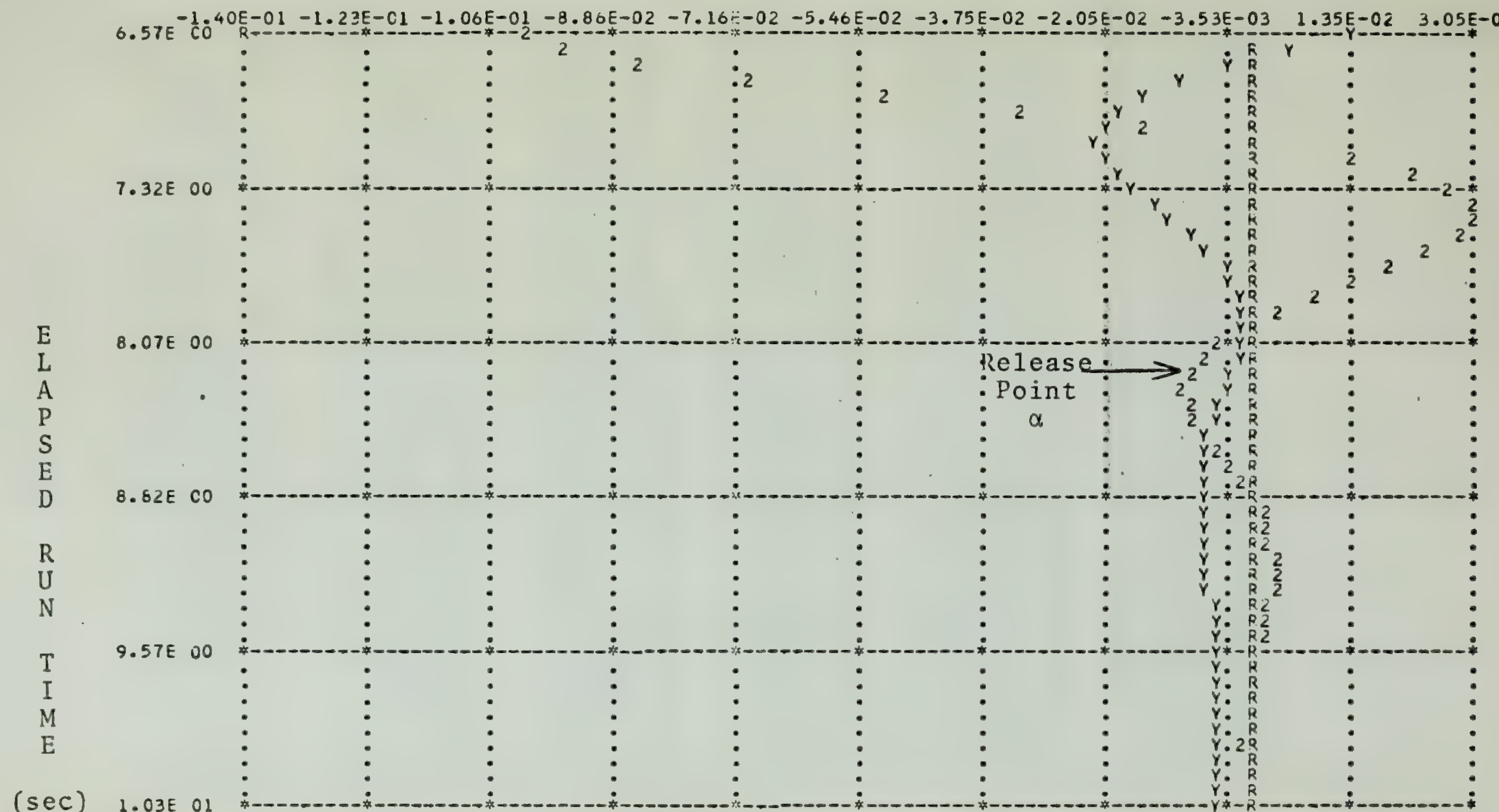
TIME	GAMMA	U	ALPHA	THETA	Q
6.575E 00	1.350E-02	6.000E-01	-1.013E-01	-8.780E-02	-1.054E-01
6.650E 00	4.526E-03	7.653E-01	-9.621E-02	-9.169E-02	-1.076E-03
6.725E 00	-3.607E-03	9.074E-01	-8.484E-02	-8.844E-02	8.401E-02
6.800E 00	-1.044E-02	1.020E 00	-6.920E-02	-7.964E-02	1.470E-01
6.875E 00	-1.570E-02	1.102E 00	-5.126E-02	-6.696E-02	1.873E-01
6.950E 00	-1.929E-02	1.153E 00	-3.279E-02	-5.208E-02	2.061E-01
7.025E 00	-2.123E-02	1.175E 00	-1.529E-02	-3.652E-02	2.059E-01
7.100E 00	-2.170E-02	1.173E 00	1.158E-04	-2.158E-02	1.902E-01
7.175E 00	-2.092E-02	1.152E 00	1.265E-02	-8.270E-03	1.632E-01
7.250E 00	-1.919E-02	1.118E 00	2.190E-02	2.715E-03	1.289E-01
7.325E 00	-1.681E-02	1.076E 00	2.779E-02	1.098E-02	9.126E-02
7.400E 00	-1.408E-02	1.032E 00	3.049E-02	1.641E-02	5.375E-02
7.475E 00	-1.127E-02	9.900E-01	3.038E-02	1.912E-02	1.916E-02
7.550E 00	-8.599E-03	9.535E-01	2.801E-02	1.941E-02	-1.046E-02
7.625E 00	-6.250E-03	9.248E-01	2.396E-02	1.771E-02	-3.380E-02
7.700E 00	-4.337E-03	9.052E-01	1.885E-02	1.451E-02	-5.026E-02
7.775E 00	-2.920E-03	8.952E-01	1.326E-02	1.034E-02	-5.988E-02
7.850E 00	-2.015E-03	8.944E-01	7.701E-03	5.686E-03	-6.321E-02
7.925E 00	-1.593E-03	9.017E-01	2.586E-03	9.923E-04	-6.115E-02
8.000E 00	-1.597E-03	9.157E-01	-1.785E-03	-3.381E-03	-5.487E-02
8.075E 00	-1.945E-03	9.348E-01	-5.219E-03	-7.164E-03	-4.562E-02
8.150E 00	-2.548E-03	9.571E-01	-7.633E-03	-1.018E-02	-3.464E-02
8.225E 00	-3.312E-03	9.810E-01	-9.034E-03	-1.235E-02	-2.308E-02
8.300E 00	-4.149E-03	1.005E 00	-9.504E-03	-1.365E-02	-1.191E-02
8.375E 00	-4.982E-03	1.028E 00	-9.181E-03	-1.416E-02	-1.912E-03
8.450E 00	-5.747E-03	1.049E 00	-8.235E-03	-1.398E-02	6.391E-03
8.525E 00	-6.400E-03	1.067E 00	-6.854E-03	-1.325E-02	1.268E-02
8.600E 00	-6.912E-03	1.082E 00	-5.221E-03	-1.213E-02	1.687E-02
8.675E 00	-7.268E-03	1.094E 00	-3.507E-03	-1.077E-02	1.902E-02
8.750E 00	-7.471E-03	1.104E 00	-1.855E-03	-9.326E-03	1.935E-02
8.825E 00	-7.533E-03	1.111E 00	-3.779E-04	-7.910E-03	1.817E-02
8.900E 00	-7.474E-03	1.116E 00	8.451E-04	-6.629E-03	1.585E-02
8.975E 00	-7.320E-03	1.120E 00	1.769E-03	-5.551E-03	1.279E-02
9.050E 00	-7.101E-03	1.123E 00	2.381E-03	-4.720E-03	9.332E-03
9.125E 00	-6.843E-03	1.126E 00	2.691E-03	-4.152E-03	5.826E-03
9.200E 00	-6.573E-03	1.129E 00	2.732E-03	-3.841E-03	2.541E-03
9.275E 00	-6.312E-03	1.132E 00	2.552E-03	-3.761E-03	-3.174E-04
9.350E 00	-6.078E-03	1.136E 00	2.204E-03	-3.874E-03	-2.613E-03
9.425E 00	-5.882E-03	1.140E 00	1.745E-03	-4.137E-03	-4.278E-03
9.500E 00	-5.731E-03	1.146E 00	1.232E-03	-4.500E-03	-5.303E-03

9.575E 00	-5.628E-03	1.152E 00	7.113E-04	-4.917E-03	-5.730E-03
9.650E 00	-5.571E-03	1.159E 00	2.247E-04	-5.346E-03	-5.638E-03
9.725E 00	-5.555E-03	1.167E 00	-1.978E-04	-5.752E-03	-5.130E-03
9.800E 00	-5.572E-03	1.175E 00	-5.365E-04	-6.108E-03	-4.320E-03
9.875E 00	-5.614E-03	1.183E 00	-7.814E-04	-6.396E-03	-3.327E-03
9.950E 00	-5.674E-03	1.192E 00	-9.316E-04	-6.605E-03	-2.258E-03
1.002E 01	-5.742E-03	1.200E 00	-9.932E-04	-6.735E-03	-1.208E-03
1.010E 01	-5.811E-03	1.209E 00	-9.783E-04	-6.789E-03	-2.525E-04
1.017E 01	-5.874E-03	1.217E 00	-9.020E-04	-6.777E-03	5.542E-04
1.025E 01	-5.929E-03	1.225E 00	-7.816E-04	-6.710E-03	1.179E-03
1.032E 01	-5.970E-03	1.232E 00	-6.343E-04	-6.605E-03	1.608E-03

GRAPHICAL TIME RESPONSE OF PERTURBATION GAMMA AND ALPHA AFTER RE-ESTABLISHMENT IN DESIRED 40° DIVE

VARIABLE	SYMBOL
GAMMA COMMANDED	R
GAMMA	Y
ALPHA	2

Perturbation Quantity (rads)



RUN 3, 1.9 DEGREES STEEP, 5 DEGREE CORRECTION

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PUSH OVER FROM 40 TO 45 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
0.0	0.0	0.0	0.0	0.0	0.0
2.500E-02	6.148E-04	8.201E-03	-2.284E-03	-1.669E-03	-1.253E-01
5.000E-02	9.137E-04	2.626E-02	-6.836E-03	-5.923E-03	-2.094E-01
7.500E-02	9.149E-04	5.273E-02	-1.282E-02	-1.191E-02	-2.656E-01
1.000E-01	6.329E-04	8.661E-02	-1.968E-02	-1.905E-02	-3.027E-01
1.250E-01	7.991E-05	1.272E-01	-2.701E-02	-2.693E-02	-3.264E-01
1.500E-01	-7.329E-04	1.738E-01	-3.455E-02	-3.529E-02	-3.406E-01
1.750E-01	-1.795E-03	2.262E-01	-4.211E-02	-4.390E-02	-3.479E-01
2.000E-01	-3.094E-03	2.839E-01	-4.954E-02	-5.263E-02	-3.500E-01
2.250E-01	-4.620E-03	3.466E-01	-5.675E-02	-6.137E-02	-3.481E-01
2.500E-01	-6.361E-03	4.139E-01	-6.365E-02	-7.001E-02	-3.431E-01
2.750E-01	-8.303E-03	4.856E-01	-7.020E-02	-7.850E-02	-3.355E-01
3.000E-01	-1.043E-02	5.614E-01	-7.634E-02	-8.677E-02	-3.258E-01
3.250E-01	-1.274E-02	6.410E-01	-8.204E-02	-9.477E-02	-3.143E-01
3.500E-01	-1.520E-02	7.241E-01	-8.727E-02	-1.025E-01	-3.013E-01
3.750E-01	-1.781E-02	8.103E-01	-9.201E-02	-1.098E-01	-2.869E-01
4.000E-01	-2.055E-02	8.994E-01	-9.626E-02	-1.168E-01	-2.715E-01
4.250E-01	-2.341E-02	9.910E-01	-9.999E-02	-1.234E-01	-2.552E-01
4.500E-01	-2.636E-02	1.085E 00	-1.032E-01	-1.296E-01	-2.381E-01
4.750E-01	-2.940E-02	1.181E 00	-1.059E-01	-1.353E-01	-2.205E-01
5.000E-01	-3.250E-02	1.278E 00	-1.081E-01	-1.406E-01	-2.025E-01
5.250E-01	-3.566E-02	1.377E 00	-1.098E-01	-1.454E-01	-1.843E-01
5.500E-01	-3.885E-02	1.477E 00	-1.109E-01	-1.498E-01	-1.659E-01
5.750E-01	-4.207E-02	1.578E 00	-1.116E-01	-1.537E-01	-1.477E-01
6.000E-01	-4.530E-02	1.680E 00	-1.119E-01	-1.572E-01	-1.296E-01
6.250E-01	-4.852E-02	1.782E 00	-1.117E-01	-1.602E-01	-1.119E-01
6.500E-01	-5.172E-02	1.883E 00	-1.111E-01	-1.628E-01	-9.468E-02
6.750E-01	-5.490E-02	1.985E 00	-1.100E-01	-1.649E-01	-7.807E-02
7.000E-01	-5.803E-02	2.087E 00	-1.087E-01	-1.667E-01	-6.220E-02
7.250E-01	-6.112E-02	2.188E 00	-1.069E-01	-1.681E-01	-4.717E-02
7.500E-01	-6.414E-02	2.289E 00	-1.049E-01	-1.691E-01	-3.310E-02
7.750E-01	-6.709E-02	2.389E 00	-1.026E-01	-1.697E-01	-2.007E-02
8.000E-01	-6.997E-02	2.489E 00	-1.001E-01	-1.701E-01	-8.182E-03
8.250E-01	-7.276E-02	2.587E 00	-9.737E-02	-1.701E-01	2.494E-03
8.500E-01	-7.547E-02	2.685E 00	-9.448E-02	-1.700E-01	1.189E-02
8.750E-01	-7.808E-02	2.781E 00	-9.147E-02	-1.696E-01	1.994E-02
9.000E-01	-8.060E-02	2.877E 00	-8.837E-02	-1.690E-01	2.662E-02

9.250E-01	-8.302E-02	2.972E 00	-8.521E-02	-1.682E-01	3.187E-02
9.500E-01	-8.534E-02	3.066E 00	-8.205E-02	-1.674E-01	3.568E-02
9.750E-01	-8.756E-02	3.159E 00	-7.890E-02	-1.665E-01	3.802E-02

TIME RESPONSE OF PERTURBATION QUANTITIES DURING 45 DEGREE DIVE

TIME	GAMMA	U	ALPHA	THETA	Q
9.750E-01	-2.900E-04	0.0	-7.591E-02	-7.620E-02	3.802E-02
1.050E 00	-6.593E-03	1.114E-01	-6.433E-02	-7.092E-02	9.970E-02
1.125E 00	-1.167E-02	2.082E-01	-5.005E-02	-6.172E-02	1.424E-01
1.200E 00	-1.535E-02	2.867E-01	-3.467E-02	-5.002E-02	1.665E-01
1.275E 00	-1.764E-02	3.449E-01	-1.953E-02	-3.717E-02	1.736E-01
1.350E 00	-1.860E-02	3.830E-01	-5.734E-03	-2.434E-02	1.663E-01
1.425E 00	-1.842E-02	4.024E-01	5.928E-03	-1.249E-02	1.479E-01
1.500E 00	-1.732E-02	4.059E-01	1.498E-02	-2.342E-03	1.218E-01
1.575E 00	-1.555E-02	3.969E-01	2.122E-02	5.665E-03	9.133E-02
1.650E 00	-1.337E-02	3.789E-01	2.470E-02	1.133E-02	5.967E-02
1.725E 00	-1.102E-02	3.557E-01	2.567E-02	1.465E-02	2.942E-02
1.800E 00	-8.705E-03	3.307E-01	2.453E-02	1.582E-02	2.570E-03
1.875E 00	-6.594E-03	3.067E-01	2.175E-02	1.516E-02	-1.948E-02
1.950E 00	-4.806E-03	2.860E-01	1.785E-02	1.304E-02	-3.595E-02
2.025E 00	-3.415E-03	2.702E-01	1.332E-02	9.909E-03	-4.666E-02
2.100E 00	-2.452E-03	2.602E-01	8.635E-03	6.183E-03	-5.185E-02
2.175E 00	-1.909E-03	2.563E-01	4.163E-03	2.254E-03	-5.217E-02
2.250E 00	-1.748E-03	2.584E-01	2.047E-04	-1.543E-03	-4.850E-02
2.325E 00	-1.910E-03	2.658E-01	-3.037E-03	-4.947E-03	-4.185E-02
2.400E 00	-2.321E-03	2.775E-01	-5.451E-03	-7.772E-03	-3.327E-02
2.475E 00	-2.904E-03	2.926E-01	-7.011E-03	-9.914E-03	-2.377E-02
2.550E 00	-3.582E-03	3.098E-01	-7.756E-03	-1.134E-02	-1.424E-02
2.625E 00	-4.286E-03	3.282E-01	-7.782E-03	-1.207E-02	-5.400E-03
2.700E 00	-4.957E-03	3.467E-01	-7.222E-03	-1.218E-02	2.216E-03
2.775E 00	-5.550E-03	3.645E-01	-6.225E-03	-1.178E-02	8.261E-03
2.850E 00	-6.035E-03	3.811E-01	-4.948E-03	-1.098E-02	1.257E-02
2.925E 00	-6.393E-03	3.960E-01	-3.540E-03	-9.933E-03	1.514E-02
3.000E 00	-6.622E-03	4.089E-01	-2.130E-03	-8.752E-03	1.611E-02
3.075E 00	-6.726E-03	4.200E-01	-8.253E-04	-7.552E-03	1.569E-02
3.150E 00	-6.721E-03	4.293E-01	2.956E-04	-6.426E-03	1.418E-02
3.225E 00	-6.627E-03	4.370E-01	1.182E-03	-5.444E-03	1.189E-02
3.300E 00	-6.466E-03	4.434E-01	1.812E-03	-4.654E-03	9.137E-03
3.375E 00	-6.262E-03	4.489E-01	2.184E-03	-4.078E-03	6.219E-03
3.450E 00	-6.038E-03	4.538E-01	2.319E-03	-3.719E-03	3.383E-03
3.525E 00	-5.813E-03	4.584E-01	2.250E-03	-3.563E-03	8.283E-04
3.600E 00	-5.605E-03	4.631E-01	2.021E-03	-3.584E-03	-1.306E-03
3.675E 00	-5.424E-03	4.679E-01	1.678E-03	-3.747E-03	-2.936E-03
3.750E 00	-5.279E-03	4.732E-01	1.268E-03	-4.011E-03	-4.034E-03
3.825E 00	-5.174E-03	4.789E-01	8.347E-04	-4.339E-03	-4.616E-03
3.900E 00	-5.107E-03	4.851E-01	4.148E-04	-4.692E-03	-4.733E-03

3.975E 00	-5.076E-03	4.919E-01	3.730E-05	-5.039E-03	-4.464E-03
4.050E 00	-5.077E-03	4.991E-01	-2.773E-04	-5.354E-03	-3.899E-03
4.125E 00	-5.102E-03	5.068E-01	-5.170E-04	-5.619E-03	-3.137E-03
4.200E 00	-5.144E-03	5.147E-01	-6.778E-04	-5.822E-03	-2.272E-03
4.275E 00	-5.197E-03	5.228E-01	-7.623E-04	-5.959E-03	-1.388E-03
4.350E 00	-5.253E-03	5.309E-01	-7.783E-04	-6.032E-03	-5.540E-04
4.425E 00	-5.308E-03	5.391E-01	-7.373E-04	-6.045E-03	1.754E-04
4.500E 00	-5.356E-03	5.472E-01	-6.532E-04	-6.009E-03	7.650E-04
4.575E 00	-5.394E-03	5.551E-01	-5.403E-04	-5.934E-03	1.196E-03
4.650E 00	-5.421E-03	5.628E-01	-4.124E-04	-5.833E-03	1.466E-03
4.725E 00	-5.436E-03	5.704E-01	-2.821E-04	-5.718E-03	1.585E-03
4.800E 00	-5.439E-03	5.777E-01	-1.596E-04	-5.599E-03	1.571E-03
4.875E 00	-5.432E-03	5.848E-01	-5.279E-05	-5.485E-03	1.450E-03
4.950E 00	-5.417E-03	5.917E-01	3.318E-05	-5.383E-03	1.251E-03
5.025E 00	-5.394E-03	5.985E-01	9.568E-05	-5.299E-03	1.004E-03
5.100E 00	-5.368E-03	6.051E-01	1.343E-04	-5.233E-03	7.355E-04
5.175E 00	-5.339E-03	6.117E-01	1.505E-04	-5.188E-03	4.706E-04
5.250E 00	-5.309E-03	6.181E-01	1.472E-04	-5.162E-03	2.281E-04
5.325E 00	-5.281E-03	6.246E-01	1.282E-04	-5.153E-03	2.228E-05
5.400E 00	-5.255E-03	6.310E-01	9.784E-05	-5.158E-03	-1.383E-04
5.475E 00	-5.233E-03	6.374E-01	6.043E-05	-5.173E-03	-2.499E-04
5.550E 00	-5.214E-03	6.438E-01	2.005E-05	-5.194E-03	-3.133E-04
5.625E 00	-5.199E-03	6.502E-01	-1.974E-05	-5.218E-03	-3.327E-04
5.700E 00	-5.187E-03	6.566E-01	-5.611E-05	-5.243E-03	-3.147E-04
5.775E 00	-5.178E-03	6.631E-01	-8.701E-05	-5.265E-03	-2.677E-04

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PULL UP FROM 45 TO 40 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
5.775E 00	-5.178E-03	6.631E-01	-8.701E-05	-5.265E-03	-2.677E-04
5.800E 00	-5.819E-03	6.611E-01	2.264E-03	-3.555E-03	1.308E-01
5.825E 00	-6.138E-03	6.558E-01	7.048E-03	9.096E-04	2.205E-01
5.850E 00	-6.141E-03	6.464E-01	1.336E-02	7.221E-03	2.804E-01
5.875E 00	-5.843E-03	6.326E-01	2.060E-02	1.476E-02	3.199E-01
5.900E 00	-5.257E-03	6.142E-01	2.836E-02	2.310E-02	3.452E-01
5.925E 00	-4.394E-03	5.909E-01	3.633E-02	3.194E-02	3.604E-01
5.950E 00	-3.266E-03	5.628E-01	4.433E-02	4.106E-02	3.682E-01
5.975E 00	-1.885E-03	5.298E-01	5.219E-02	5.031E-02	3.706E-01
6.000E 00	-2.622E-04	4.920E-01	5.982E-02	5.955E-02	3.687E-01
6.025E 00	1.588E-03	4.494E-01	6.712E-02	6.871E-02	3.634E-01
6.050E 00	3.654E-03	4.022E-01	7.405E-02	7.770E-02	3.554E-01
6.075E 00	5.919E-03	3.505E-01	8.054E-02	8.646E-02	3.451E-01
6.100E 00	8.371E-03	2.946E-01	8.657E-02	9.494E-02	3.330E-01
6.125E 00	1.099E-02	2.345E-01	9.210E-02	1.031E-01	3.192E-01
6.150E 00	1.377E-02	1.706E-01	9.712E-02	1.109E-01	3.040E-01
6.175E 00	1.668E-02	1.030E-01	1.016E-01	1.183E-01	2.877E-01
6.200E 00	1.972E-02	3.197E-02	1.055E-01	1.253E-01	2.704E-01
6.225E 00	2.286E-02	-4.225E-02	1.089E-01	1.318E-01	2.523E-01
6.250E 00	2.609E-02	-1.194E-01	1.118E-01	1.379E-01	2.336E-01
6.275E 00	2.939E-02	-1.993E-01	1.141E-01	1.435E-01	2.146E-01
6.300E 00	3.275E-02	-2.815E-01	1.158E-01	1.486E-01	1.952E-01
6.325E 00	3.615E-02	-3.660E-01	1.171E-01	1.532E-01	1.758E-01
6.350E 00	3.957E-02	-4.523E-01	1.178E-01	1.574E-01	1.564E-01
6.375E 00	4.300E-02	-5.404E-01	1.181E-01	1.611E-01	1.373E-01
6.400E 00	4.643E-02	-6.298E-01	1.178E-01	1.642E-01	1.185E-01
6.425E 00	4.984E-02	-7.204E-01	1.171E-01	1.670E-01	1.002E-01
6.450E 00	5.321E-02	-8.120E-01	1.161E-01	1.693E-01	8.259E-02
6.475E 00	5.655E-02	-9.043E-01	1.146E-01	1.711E-01	6.574E-02
6.500E 00	5.982E-02	-9.972E-01	1.127E-01	1.726E-01	4.980E-02
6.525E 00	6.304E-02	-1.090E 00	1.106E-01	1.736E-01	3.486E-02
6.550E 00	6.617E-02	-1.184E 00	1.081E-01	1.743E-01	2.104E-02
6.575E 00	6.923E-02	-1.277E 00	1.054E-01	1.747E-01	8.413E-03
6.600E 00	7.220E-02	-1.370E 00	1.025E-01	1.747E-01	-2.924E-03
6.625E 00	7.507E-02	-1.463E 00	9.947E-02	1.745E-01	-1.290E-02
6.650E 00	7.784E-02	-1.556E 00	9.626E-02	1.741E-01	-2.147E-02
6.675E 00	8.051E-02	-1.648E 00	9.296E-02	1.735E-01	-2.856E-02
6.699E 00	8.308E-02	-1.740E 00	8.961E-02	1.727E-01	-3.416E-02
6.724E 00	8.554E-02	-1.831E 00	8.624E-02	1.718E-01	-3.822E-02
6.749E 00	8.790E-02	-1.922E 00	8.289E-02	1.708E-01	-4.074E-02

TIME RESPONSE OF PERTURBATION QUANTITIES DURING 40 DEGREE DIVE

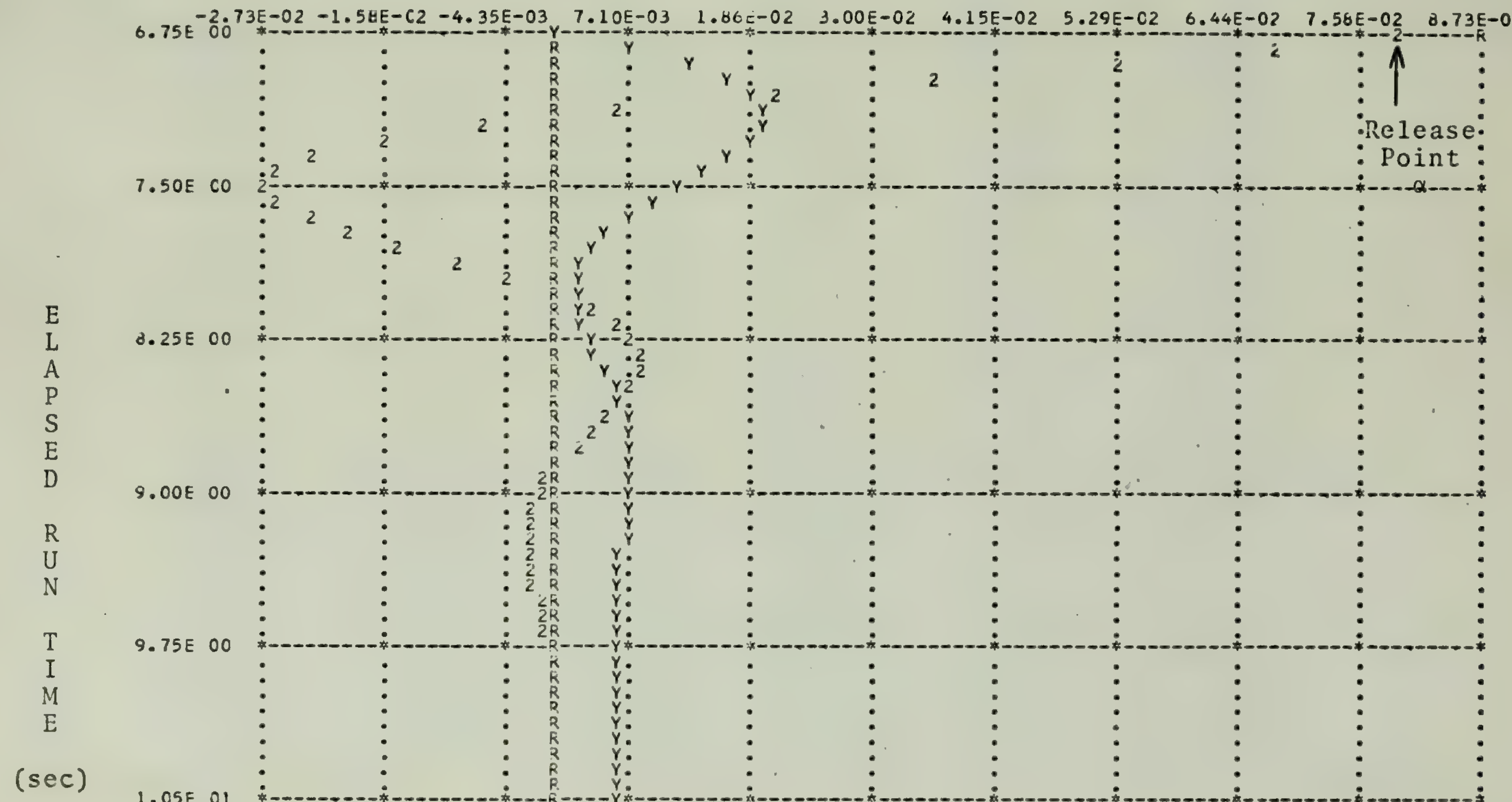
TIME	GAMMA	U	ALPHA	THETA	Q
6.750E 00	6.200E-04	1.300E 00	7.978E-02	8.040E-02	-4.106E-02
6.825E 00	7.212E-03	1.180E 00	6.756E-02	7.477E-02	-1.059E-01
6.900E 00	1.251E-02	1.087E 00	5.251E-02	6.502E-02	-1.507E-01
6.975E 00	1.636E-02	1.022E 00	3.629E-02	5.265E-02	-1.759E-01
7.050E 00	1.874E-02	9.829E-01	2.034E-02	3.908E-02	-1.832E-01
7.125E 00	1.974E-02	9.673E-01	5.804E-03	2.555E-02	-1.754E-01
7.200E 00	1.954E-02	9.707E-01	-6.482E-03	1.306E-02	-1.559E-01
7.275E 00	1.838E-02	9.881E-01	-1.601E-02	2.364E-03	-1.283E-01
7.350E 00	1.651E-02	1.014E 00	-2.258E-02	-6.067E-03	-9.610E-02
7.425E 00	1.422E-02	1.045E 00	-2.624E-02	-1.202E-02	-6.268E-02
7.500E 00	1.175E-02	1.075E 00	-2.726E-02	-1.551E-02	-3.075E-02
7.575E 00	9.320E-03	1.102E 00	-2.604E-02	-1.672E-02	-2.432E-03
7.650E 00	7.104E-03	1.123E 00	-2.310E-02	-1.600E-02	2.082E-02
7.725E 00	5.228E-03	1.137E 00	-1.898E-02	-1.375E-02	3.818E-02
7.800E 00	3.769E-03	1.142E 00	-1.419E-02	-1.042E-02	4.945E-02
7.875E 00	2.760E-03	1.139E 00	-9.236E-03	-6.476E-03	5.490E-02
7.950E 00	2.192E-03	1.128E 00	-4.510E-03	-2.318E-03	5.521E-02
8.025E 00	2.025E-03	1.111E 00	-3.260E-04	1.699E-03	5.129E-02
8.100E 00	2.197E-03	1.088E 00	3.101E-03	5.298E-03	4.424E-02
8.175E 00	2.631E-03	1.062E 00	5.653E-03	8.284E-03	3.515E-02
8.250E 00	3.246E-03	1.034E 00	7.301E-03	1.055E-02	2.510E-02
8.325E 00	3.960E-03	1.006E 00	8.088E-03	1.205E-02	1.501E-02
8.400E 00	4.701E-03	9.774E-01	8.116E-03	1.282E-02	5.651E-03
8.475E 00	5.407E-03	9.507E-01	7.521E-03	1.293E-02	-2.408E-03
8.550E 00	6.031E-03	9.262E-01	6.466E-03	1.250E-02	-8.802E-03
8.625E 00	6.541E-03	9.042E-01	5.113E-03	1.165E-02	-1.336E-02
8.700E 00	6.918E-03	8.848E-01	3.621E-03	1.054E-02	-1.608E-02
8.775E 00	7.158E-03	8.680E-01	2.128E-03	9.285E-03	-1.709E-02
8.850E 00	7.267E-03	8.535E-01	7.453E-04	8.012E-03	-1.664E-02
8.925E 00	7.261E-03	8.409E-01	-4.425E-04	6.818E-03	-1.503E-02
9.000E 00	7.160E-03	8.298E-01	-1.382E-03	5.778E-03	-1.260E-02
9.075E 00	6.990E-03	8.196E-01	-2.049E-03	4.941E-03	-9.679E-03
9.150E 00	6.774E-03	8.100E-01	-2.444E-03	4.331E-03	-6.581E-03
9.225E 00	6.538E-03	8.005E-01	-2.586E-03	3.951E-03	-3.571E-03
9.300E 00	6.300E-03	7.908E-01	-2.513E-03	3.788E-03	-8.589E-04
9.375E 00	6.080E-03	7.806E-01	-2.269E-03	3.811E-03	1.406E-03
9.450E 00	5.889E-03	7.699E-01	-1.904E-03	3.985E-03	3.137E-03
9.525E 00	5.736E-03	7.584E-01	-1.469E-03	4.268E-03	4.302E-03
9.600E 00	5.624E-03	7.462E-01	-1.008E-03	4.617E-03	4.919E-03
9.675E 00	5.554E-03	7.333E-01	-5.603E-04	4.993E-03	5.043E-03

9.750E 00	5.522E-03	7.199E-01	-1.589E-04	5.363E-03	4.755E-03
9.825E 00	5.522E-03	7.060E-01	1.763E-04	5.698E-03	4.154E-03
9.900E 00	5.549E-03	6.918E-01	4.319E-04	5.981E-03	3.344E-03
9.975E 00	5.593E-03	6.775E-01	6.037E-04	6.197E-03	2.423E-03
1.005E 01	5.649E-03	6.631E-01	6.942E-04	6.343E-03	1.481E-03
1.012E 01	5.709E-03	6.488E-01	7.119E-04	6.421E-03	5.936E-04
1.020E 01	5.766E-03	6.347E-01	6.690E-04	6.435E-03	-1.829E-04
1.027E 01	5.817E-03	6.208E-01	5.800E-04	6.397E-03	-8.107E-04
1.035E 01	5.857E-03	6.072E-01	4.603E-04	6.318E-03	-1.270E-03
1.042E 01	5.886E-03	5.939E-01	3.246E-04	6.211E-03	-1.558E-03
1.050E 01	5.902E-03	5.809E-01	1.862E-04	6.088E-03	-1.684E-03

GRAPHICAL TIME RESPONSE OF PERTURBATION GAMMA AND ALPHA AFTER RE-ESTABLISHMENT IN DESIRED 40° DIVE

VARIABLE	SYMBOL
GAMMA COMMANDED	R
GAMMA	Y
ALPHA	2

Perturbation Quantity (rads)



RUN 4, 1.9 DEGREES STEEP, 8 DEGREE CORRECTION

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PUSH OVER FROM 40 TO 48 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
0.0	0.0	0.0	0.0	0.0	0.0
2.500E-02	6.285E-04	8.386E-03	-2.336E-03	-1.707E-03	-1.281E-01
5.000E-02	9.328E-04	2.684E-02	-6.986E-03	-6.053E-03	-2.138E-01
7.500E-02	9.331E-04	5.386E-02	-1.310E-02	-1.216E-02	-2.711E-01
1.000E-01	6.450E-04	8.843E-02	-2.009E-02	-1.945E-02	-3.089E-01
1.250E-01	8.154E-05	1.298E-01	-2.758E-02	-2.750E-02	-3.333E-01
1.500E-01	-7.458E-04	1.775E-01	-3.529E-02	-3.603E-02	-3.463E-01
1.750E-01	-1.826E-03	2.311E-01	-4.303E-02	-4.485E-02	-3.565E-01
2.000E-01	-3.149E-03	2.902E-01	-5.067E-02	-5.382E-02	-3.599E-01
2.250E-01	-4.703E-03	3.546E-01	-5.811E-02	-6.282E-02	-3.595E-01
2.500E-01	-6.477E-03	4.239E-01	-6.529E-02	-7.177E-02	-3.563E-01
2.750E-01	-8.459E-03	4.980E-01	-7.215E-02	-8.061E-02	-3.508E-01
3.000E-01	-1.064E-02	5.766E-01	-7.865E-02	-8.929E-02	-3.434E-01
3.250E-01	-1.300E-02	6.594E-01	-8.477E-02	-9.777E-02	-3.345E-01
3.500E-01	-1.554E-02	7.462E-01	-9.047E-02	-1.060E-01	-3.243E-01
3.750E-01	-1.823E-02	8.368E-01	-9.575E-02	-1.140E-01	-3.131E-01
4.000E-01	-2.107E-02	9.309E-01	-1.006E-01	-1.217E-01	-3.009E-01
4.250E-01	-2.404E-02	1.028E 00	-1.050E-01	-1.290E-01	-2.880E-01
4.500E-01	-2.712E-02	1.129E 00	-1.089E-01	-1.360E-01	-2.745E-01
4.750E-01	-3.031E-02	1.232E 00	-1.124E-01	-1.427E-01	-2.605E-01
5.000E-01	-3.360E-02	1.338E 00	-1.155E-01	-1.491E-01	-2.462E-01
5.250E-01	-3.696E-02	1.446E 00	-1.181E-01	-1.550E-01	-2.317E-01
5.500E-01	-4.038E-02	1.556E 00	-1.203E-01	-1.607E-01	-2.172E-01
5.750E-01	-4.386E-02	1.668E 00	-1.220E-01	-1.659E-01	-2.026E-01
6.000E-01	-4.738E-02	1.782E 00	-1.234E-01	-1.708E-01	-1.883E-01
6.250E-01	-5.093E-02	1.897E 00	-1.244E-01	-1.753E-01	-1.741E-01
6.500E-01	-5.449E-02	2.014E 00	-1.250E-01	-1.795E-01	-1.604E-01
6.750E-01	-5.807E-02	2.132E 00	-1.253E-01	-1.833E-01	-1.471E-01
7.000E-01	-6.163E-02	2.251E 00	-1.252E-01	-1.869E-01	-1.344E-01
7.250E-01	-6.519E-02	2.371E 00	-1.249E-01	-1.901E-01	-1.224E-01
7.500E-01	-6.873E-02	2.491E 00	-1.243E-01	-1.930E-01	-1.111E-01
7.750E-01	-7.223E-02	2.613E 00	-1.234E-01	-1.956E-01	-1.006E-01
8.000E-01	-7.571E-02	2.734E 00	-1.223E-01	-1.980E-01	-9.105E-02
8.250E-01	-7.914E-02	2.857E 00	-1.210E-01	-2.002E-01	-8.244E-02
8.500E-01	-8.252E-02	2.980E 00	-1.196E-01	-2.021E-01	-7.485E-02
8.750E-01	-8.586E-02	3.103E 00	-1.181E-01	-2.039E-01	-6.833E-02
9.000E-01	-8.914E-02	3.227E 00	-1.164E-01	-2.056E-01	-6.293E-02

9.250E-01	-9.236E-02	3.352E 00	-1.147E-01	-2.071E-01	-5.868E-02
9.500E-01	-9.553E-02	3.477E 00	-1.130E-01	-2.085E-01	-5.561E-02
9.750E-01	-9.864E-02	3.602E 00	-1.112E-01	-2.099E-01	-5.374E-02
1.000E 00	-1.017E-01	3.728E 00	-1.095E-01	-2.112E-01	-5.309E-02
1.025E 00	-1.047E-01	3.855E 00	-1.079E-01	-2.125E-01	-5.366E-02
1.050E 00	-1.076E-01	3.983E 00	-1.063E-01	-2.139E-01	-5.544E-02
1.075E 00	-1.105E-01	4.112E 00	-1.048E-01	-2.153E-01	-5.844E-02
1.100E 00	-1.134E-01	4.242E 00	-1.035E-01	-2.168E-01	-6.262E-02
1.125E 00	-1.162E-01	4.373E 00	-1.023E-01	-2.185E-01	-6.798E-02
1.150E 00	-1.189E-01	4.506E 00	-1.013E-01	-2.202E-01	-7.448E-02
1.175E 00	-1.217E-01	4.640E 00	-1.005E-01	-2.222E-01	-8.208E-02
1.200E 00	-1.244E-01	4.777E 00	-9.999E-02	-2.244E-01	-9.075E-02
1.225E 00	-1.270E-01	4.915E 00	-9.970E-02	-2.267E-01	-1.004E-01

TIME RESPONSE OF PERTURBATION QUANTITIES DURING 48 DEGREE DIVE

TIME	GAMMA	U	ALPHA	THETA	Q
1.225E 00	1.271E-02	0.0	-9.521E-02	-8.250E-02	-1.004E-01
1.300E 00	4.193E-03	9.829E-02	-9.044E-02	-8.624E-02	-2.131E-03
1.375E 00	-3.525E-03	2.020E-01	-7.975E-02	-8.327E-02	7.805E-02
1.450E 00	-1.001E-02	3.028E-01	-6.505E-02	-7.506E-02	1.375E-01
1.525E 00	-1.500E-02	3.943E-01	-4.819E-02	-6.319E-02	1.755E-01
1.600E 00	-1.840E-02	4.720E-01	-3.084E-02	-4.924E-02	1.933E-01
1.675E 00	-2.025E-02	5.331E-01	-1.440E-02	-3.465E-02	1.932E-01
1.750E 00	-2.069E-02	5.767E-01	6.801E-05	-2.063E-02	1.786E-01
1.825E 00	-1.996E-02	6.034E-01	1.184E-02	-8.124E-03	1.533E-01
1.900E 00	-1.832E-02	6.149E-01	2.052E-02	2.200E-03	1.212E-01
1.975E 00	-1.607E-02	6.136E-01	2.604E-02	9.975E-03	8.591E-02
2.050E 00	-1.348E-02	6.027E-01	2.857E-02	1.509E-02	5.075E-02
2.125E 00	-1.082E-02	5.854E-01	2.848E-02	1.766E-02	1.831E-02
2.200E 00	-8.300E-03	5.646E-01	2.625E-02	1.795E-02	-9.461E-03
2.275E 00	-6.077E-03	5.431E-01	2.246E-02	1.638E-02	-3.135E-02
2.350E 00	-4.266E-03	5.233E-01	1.768E-02	1.341E-02	-4.679E-02
2.425E 00	-2.924E-03	5.069E-01	1.245E-02	9.525E-03	-5.584E-02
2.500E 00	-2.066E-03	4.949E-01	7.251E-03	5.185E-03	-5.898E-02
2.575E 00	-1.664E-03	4.881E-01	2.468E-03	8.043E-04	-5.709E-02
2.650E 00	-1.663E-03	4.866E-01	-1.617E-03	-3.279E-03	-5.124E-02
2.725E 00	-1.987E-03	4.899E-01	-4.825E-03	-6.812E-03	-4.261E-02
2.800E 00	-2.551E-03	4.975E-01	-7.079E-03	-9.631E-03	-3.237E-02
2.875E 00	-3.267E-03	5.085E-01	-8.387E-03	-1.165E-02	-2.158E-02
2.950E 00	-4.052E-03	5.221E-01	-8.824E-03	-1.288E-02	-1.115E-02
3.025E 00	-4.832E-03	5.371E-01	-8.522E-03	-1.335E-02	-1.819E-03
3.100E 00	-5.550E-03	5.528E-01	-7.639E-03	-1.319E-02	5.931E-03
3.175E 00	-6.161E-03	5.683E-01	-6.351E-03	-1.251E-02	1.181E-02
3.250E 00	-6.638E-03	5.831E-01	-4.829E-03	-1.147E-02	1.571E-02
3.325E 00	-6.970E-03	5.965E-01	-3.232E-03	-1.020E-02	1.772E-02
3.400E 00	-7.158E-03	6.085E-01	-1.694E-03	-8.852E-03	1.804E-02
3.475E 00	-7.213E-03	6.188E-01	-3.194E-04	-7.532E-03	1.695E-02
3.550E 00	-7.154E-03	6.275E-01	8.182E-04	-6.336E-03	1.480E-02
3.625E 00	-7.007E-03	6.347E-01	1.677E-03	-5.330E-03	1.195E-02
3.700E 00	-6.798E-03	6.407E-01	2.245E-03	-4.553E-03	8.736E-03
3.775E 00	-6.553E-03	6.457E-01	2.533E-03	-4.021E-03	5.478E-03
3.850E 00	-6.297E-03	6.499E-01	2.571E-03	-3.726E-03	2.425E-03
3.925E 00	-6.049E-03	6.538E-01	2.402E-03	-3.647E-03	-2.305E-04
4.000E 00	-5.827E-03	6.575E-01	2.079E-03	-3.748E-03	-2.363E-03
4.075E 00	-5.640E-03	6.612E-01	1.653E-03	-3.987E-03	-3.910E-03
4.150E 00	-5.496E-03	6.652E-01	1.177E-03	-4.319E-03	-4.862E-03

4.225E 00	-5.396E-03	6.696E-01	6.943E-04	-4.702E-03	-5.260E-03
4.300E 00	-5.339E-03	6.744E-01	2.434E-04	-5.096E-03	-5.175E-03
4.375E 00	-5.321E-03	6.796E-01	-1.479E-04	-5.469E-03	-4.705E-03

TIME RESPONSE OF PERTURBATION QUANTITIES DURING PULL UP FROM 48 TO 40 DEGREES

TIME	GAMMA	U	ALPHA	THETA	Q
4.375E 00	-5.321E-03	6.796E-01	-1.479E-04	-5.469E-03	-4.705E-03
4.400E 00	-5.967E-03	6.796E-01	2.102E-03	-3.865E-03	1.267E-01
4.425E 00	-6.291E-03	6.802E-01	6.793E-03	5.016E-04	2.166E-01
4.450E 00	-6.302E-03	6.797E-01	1.302E-02	6.719E-03	2.767E-01
4.475E 00	-6.014E-03	6.773E-01	2.018E-02	1.417E-02	3.165E-01
4.500E 00	-5.440E-03	6.722E-01	2.787E-02	2.243E-02	3.423E-01
4.525E 00	-4.592E-03	6.638E-01	3.580E-02	3.120E-02	3.584E-01
4.550E 00	-3.482E-03	6.520E-01	4.377E-02	4.029E-02	3.674E-01
4.575E 00	-2.119E-03	6.364E-01	5.165E-02	4.953E-02	3.713E-01
4.600E 00	-5.156E-04	6.170E-01	5.934E-02	5.882E-02	3.713E-01
4.625E 00	1.317E-03	5.937E-01	6.675E-02	6.807E-02	3.684E-01
4.650E 00	3.368E-03	5.664E-01	7.385E-02	7.722E-02	3.630E-01
4.675E 00	5.623E-03	5.352E-01	8.058E-02	8.620E-02	3.557E-01
4.700E 00	8.071E-03	5.001E-01	8.692E-02	9.499E-02	3.468E-01
4.725E 00	1.070E-02	4.612E-01	9.284E-02	1.035E-01	3.366E-01
4.750E 00	1.349E-02	4.185E-01	9.832E-02	1.118E-01	3.252E-01
4.775E 00	1.644E-02	3.721E-01	1.034E-01	1.198E-01	3.129E-01
4.800E 00	1.952E-02	3.222E-01	1.079E-01	1.274E-01	2.998E-01
4.825E 00	2.273E-02	2.689E-01	1.120E-01	1.348E-01	2.861E-01
4.850E 00	2.604E-02	2.122E-01	1.157E-01	1.417E-01	2.718E-01
4.875E 00	2.946E-02	1.523E-01	1.189E-01	1.484E-01	2.572E-01
4.900E 00	3.295E-02	8.939E-02	1.217E-01	1.546E-01	2.424E-01
4.925E 00	3.652E-02	2.356E-02	1.240E-01	1.605E-01	2.274E-01
4.950E 00	4.014E-02	-4.503E-02	1.258E-01	1.660E-01	2.125E-01
4.975E 00	4.380E-02	-1.162E-01	1.273E-01	1.711E-01	1.977E-01
5.000E 00	4.750E-02	-1.899E-01	1.284E-01	1.759E-01	1.832E-01
5.025E 00	5.121E-02	-2.659E-01	1.291E-01	1.803E-01	1.690E-01
5.050E 00	5.494E-02	-3.440E-01	1.294E-01	1.843E-01	1.553E-01
5.075E 00	5.866E-02	-4.241E-01	1.294E-01	1.880E-01	1.422E-01
5.100E 00	6.237E-02	-5.061E-01	1.291E-01	1.914E-01	1.297E-01
5.125E 00	6.606E-02	-5.899E-01	1.285E-01	1.945E-01	1.180E-01
5.150E 00	6.972E-02	-6.753E-01	1.276E-01	1.973E-01	1.071E-01
5.175E 00	7.334E-02	-7.621E-01	1.265E-01	1.999E-01	9.715E-02
5.200E 00	7.693E-02	-8.503E-01	1.253E-01	2.022E-01	8.817E-02
5.225E 00	8.046E-02	-9.398E-01	1.238E-01	2.043E-01	8.024E-02
5.250E 00	8.395E-02	-1.030E 00	1.223E-01	2.062E-01	7.341E-02
5.275E 00	8.738E-02	-1.122E 00	1.206E-01	2.080E-01	6.773E-02
5.299E 00	9.075E-02	-1.215E 00	1.189E-01	2.096E-01	6.323E-02
5.324E 00	9.406E-02	-1.308E 00	1.171E-01	2.112E-01	5.995E-02
5.349E 00	9.731E-02	-1.403E 00	1.153E-01	2.126E-01	5.792E-02

5.374E 00	1.005E-01	-1.498E 00	1.136E-01	2.141E-01	5.714E-02
5.399E 00	1.036E-01	-1.594E 00	1.119E-01	2.155E-01	5.762E-02
5.424E 00	1.067E-01	-1.691E 00	1.102E-01	2.170E-01	5.937E-02
5.449E 00	1.097E-01	-1.789E 00	1.087E-01	2.185E-01	6.237E-02
5.474E 00	1.127E-01	-1.888E 00	1.074E-01	2.201E-01	6.661E-02
5.499E 00	1.156E-01	-1.987E 00	1.062E-01	2.218E-01	7.206E-02
5.524E 00	1.185E-01	-2.088E 00	1.052E-01	2.237E-01	7.871E-02
5.549E 00	1.214E-01	-2.189E 00	1.044E-01	2.258E-01	8.651E-02
5.574E 00	1.242E-01	-2.291E 00	1.038E-01	2.280E-01	9.542E-02

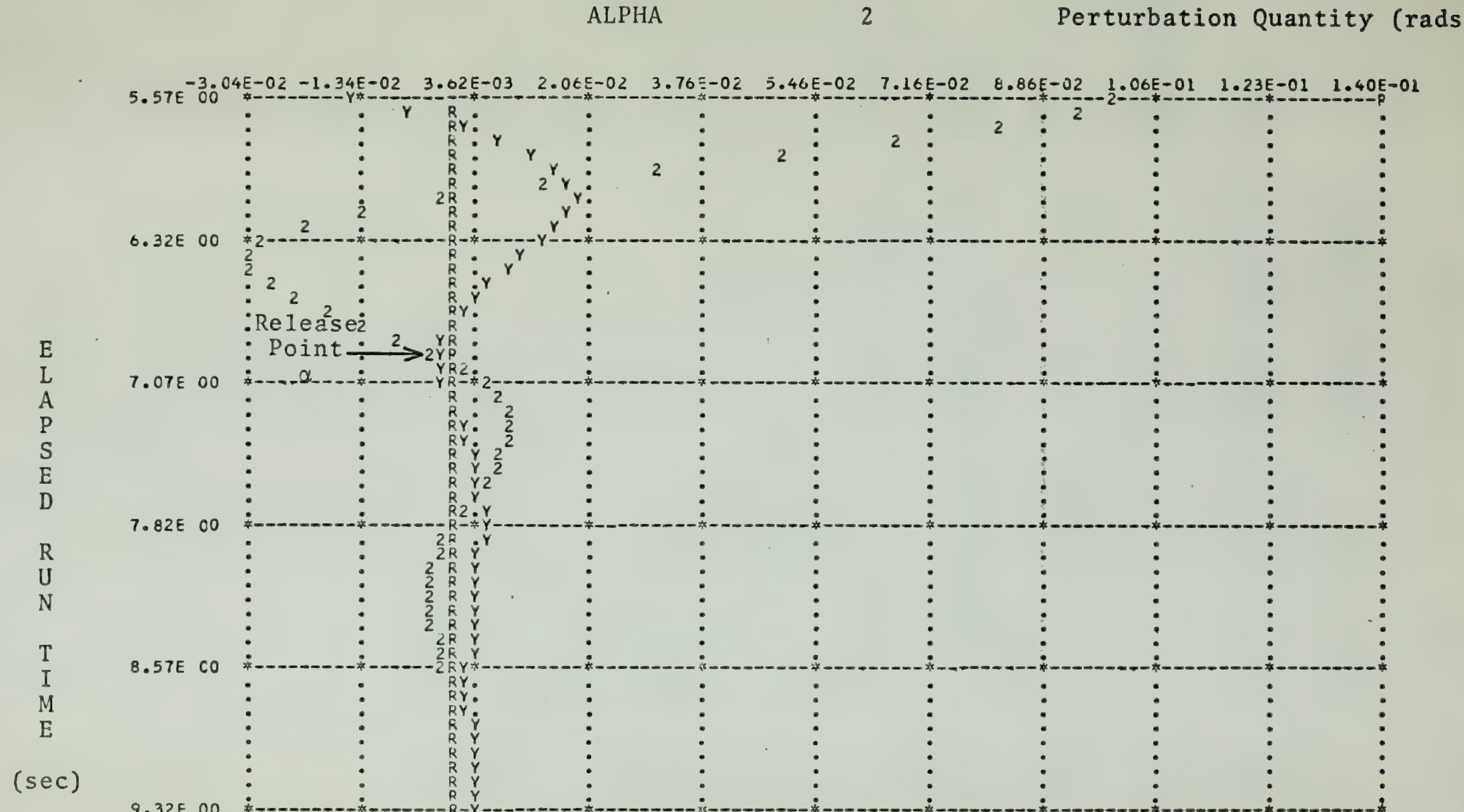
TIME RESPONSE OF PERTURBATION QUANTITIES CURING 40 DEGREE DIVE

TIME	GAMMA	U	ALPHA	THETA	Q
5.575E 00	-1.551E-02	2.608E 00	9.921E-02	8.370E-02	9.518E-02
5.650E 00	-6.722E-03	2.442E 00	9.365E-02	8.693E-02	-6.122E-03
5.725E 00	1.196E-03	2.299E 00	8.207E-02	8.326E-02	-8.820E-02
5.800E 00	7.810E-03	2.185E 00	6.644E-02	7.425E-02	-1.485E-01
5.875E 00	1.286E-02	2.102E 00	4.869E-02	6.155E-02	-1.864E-01
5.950E 00	1.626E-02	2.049E 00	3.055E-02	4.682E-02	-2.033E-01
6.025E 00	1.806E-02	2.024E 00	1.346E-02	3.153E-02	-2.017E-01
6.100E 00	1.842E-02	2.023E 00	-1.491E-03	1.693E-02	-1.853E-01
6.175E 00	1.758E-02	2.039E 00	-1.358E-02	3.997E-03	-1.580E-01
6.250E 00	1.582E-02	2.069E 00	-2.242E-02	-6.607E-03	-1.239E-01
6.325E 00	1.344E-02	2.105E 00	-2.796E-02	-1.452E-02	-8.680E-02
6.400E 00	1.074E-02	2.143E 00	-3.038E-02	-1.964E-02	-5.003E-02
6.475E 00	7.987E-03	2.179E 00	-3.008E-02	-2.210E-02	-1.632E-02
6.550E 00	5.387E-03	2.209E 00	-2.760E-02	-2.221E-02	1.237E-02
6.625E 00	3.111E-03	2.232E 00	-2.351E-02	-2.040E-02	3.481E-02
6.700E 00	1.269E-03	2.245E 00	-1.843E-02	-1.716E-02	5.047E-02
6.775E 00	-8.047E-05	2.249E 00	-1.291E-02	-1.300E-02	5.943E-02
6.850E 00	-9.284E-04	2.244E 00	-7.468E-03	-8.396E-03	6.226E-02
6.925E 00	-1.304E-03	2.232E 00	-2.483E-03	-3.787E-03	5.987E-02
7.000E 00	-1.267E-03	2.212E 00	1.750E-03	4.829E-04	5.342E-02
7.075E 00	-8.974E-04	2.188E 00	5.053E-03	4.155E-03	4.414E-02
7.150E 00	-2.847E-04	2.161E 00	7.349E-03	7.064E-03	3.326E-02
7.225E 00	4.795E-04	2.132E 00	8.652E-03	9.132E-03	2.168E-02
7.300E 00	1.309E-03	2.104E 00	9.049E-03	1.036E-02	1.097E-02
7.375E 00	2.129E-03	2.077E 00	8.677E-03	1.081E-02	1.241E-03
7.450E 00	2.880E-03	2.051E 00	7.707E-03	1.059E-02	-6.780E-03
7.525E 00	3.516E-03	2.029E 00	6.323E-03	9.839E-03	-1.281E-02
7.600E 00	4.011E-03	2.009E 00	4.706E-03	8.718E-03	-1.676E-02
7.675E 00	4.354E-03	1.992E 00	3.020E-03	7.375E-03	-1.873E-02
7.750E 00	4.547E-03	1.978E 00	1.406E-03	5.952E-03	-1.893E-02
7.825E 00	4.601E-03	1.966E 00	-2.947E-05	4.572E-03	-1.767E-02
7.900E 00	4.539E-03	1.956E 00	-1.210E-03	3.329E-03	-1.532E-02
7.975E 00	4.386E-03	1.947E 00	-2.095E-03	2.291E-03	-1.226E-02
8.050E 00	4.171E-03	1.940E 00	-2.672E-03	1.499E-03	-8.848E-03
8.125E 00	3.919E-03	1.932E 00	-2.955E-03	9.647E-04	-5.408E-03
8.200E 00	3.658E-03	1.924E 00	-2.976E-03	6.814E-04	-2.203E-03
8.275E 00	3.407E-03	1.916E 00	-2.783E-03	6.234E-04	5.699E-04
8.350E 00	3.183E-03	1.908E 00	-2.430E-03	7.528E-04	2.781E-03
8.425E 00	2.998E-03	1.898E 00	-1.973E-03	1.025E-03	4.369E-03
8.500E 00	2.857E-03	1.888E 00	-1.465E-03	1.393E-03	5.330E-03

8.575E 00	2.764E-03	1.877E 00	-9.538E-04	1.810E-03	5.707E-03
8.650E 00	2.715E-03	1.865E 00	-4.787E-04	2.236E-03	5.580E-03
8.725E 00	2.705E-03	1.853E 00	-6.845E-05	2.637E-03	5.053E-03
8.800E 00	2.729E-03	1.840E 00	2.582E-04	2.987E-03	4.239E-03
8.875E 00	2.776E-03	1.827E 00	4.923E-04	3.268E-03	3.252E-03
8.950E 00	2.840E-03	1.814E 00	6.333E-04	3.473E-03	2.199E-03
9.025E 00	2.911E-03	1.800E 00	6.881E-04	3.599E-03	1.171E-03
9.100E 00	2.982E-03	1.787E 00	6.686E-04	3.651E-03	2.405E-04
9.175E 00	3.049E-03	1.775E 00	5.901E-04	3.639E-03	-5.401E-04
9.250E 00	3.105E-03	1.762E 00	4.694E-04	3.574E-03	-1.140E-03
9.325E 00	3.149E-03	1.750E 00	3.237E-04	3.472E-03	-1.548E-03

GRAPHICAL TIME RESPONSE OF PERTURBATION GAMMA AND ALPHA AFTER RE-ESTABLISHMENT IN DESIRED 40° DIVE

VARIABLE	SYMBOL
GAMMA COMMANDED	R
GAMMA	Y
ALPHA	2



USER MAIN PROGRAM, EMPLOYED TO START EACH PHASE OF A DELIVERY MANEUVER

```
   CALL GTRESP
   CALL GTRESP
   CALL GTRESP
   CALL GTRESP
01 STOP
   END
```

TYPICAL USER SUBROUTINE, EMPLOYED TO SET START TIME FOR EACH PHASE OF MANEUVER

```
   SUBROUTINE RFIND(T,R)
   IF(T.GT.0.975) GO TO 2
   R=.08725
   RETURN
 2 IF(T.GT.7.2) GO TO 3
   R=0.
   RETURN
 3 IF(T.GT.8.175) GO TO 4
   R=-0.08725
   RETURN
 4 IF(T.GT.15.675) GO TO 5
   R=0.
 5 RETURN
   END
```

PRIMARY SUBROUTINE, EMPLOYED TO CALL ALL OTHER ROUTINES FOR COMPUTING, BY FOURTH ORDER RUNGE KUTTA NUMERICAL INTEGRATION, AND PLOTTING THE TIME RESPONSE OF THE PERTURBATION QUANTITIES TO A COMMANDED DIVE ANGLE CHANGE

```
         SUBROUTINE GTRESP
C     GRAPHICAL TIME RESPONSE (GTRESP)
C     SUBPROGRAMS USED- CALCU, RUNGE, TRESP, YDOT
       INTEGER CHAR(15)
       COMMON IPLOT,IVAR(10)
       DIMENSION A(10,10),C(10),B(10), AK(10),X(10),NAME(5)
       DATA CHAR(1),CHAR(2),CHAR(3),CHAR(4),CHAR(5),
      *CHAR(6),CHAR(7),CHAR(8),CHAR(9),CHAR(10),CHAR(11),
      *CHAR(12),CHAR(13),CHAR(14),CHAR(15)/2H 1,2H 2,2H 3,2H0
      *4,2H 5,2H 6,2H 7,2H 8,2H 9,2H10,2H E,2H U,2H Y,2H R,
      *2H  /
     3 FORMAT (8F10.3)
  1000 FORMAT (1H0, 10X, 8HTZERO = , F10.6,10X, 5HTF = ,F10.6
      */
      * 11X,5HDT = ,F10.6,13X,7HFREQ = I5)
  1001 FORMAT (1H0,10X,13H THE A MATRIX   /)
  1002 FORMAT (6(1PE20.8))
  1003 FORMAT (1H0,10X,19H INITIAL CONDITIONS     /)
  1004 FORMAT (1H0,10X,13H THE B MATRIX   /)
  1005 FORMAT (1H0,10X,16H FEEDBACK COEFF.      /)
  1006 FORMAT (1H0,10X,8H GAIN = , 1PE20.8  )
  1007 FORMAT (1H0,10X,13H THE C MATRIX   /)
  1008 FORMAT (8A2)
  1009 FORMAT( 5X,25HPROBLEM IDENTIFICATION - ,5A4)
  1010 FORMAT(1H1,4X,23HGRAPHICAL TIME RESPONSE)
  1011 FORMAT(/5X,45(1H*))
    10 READ(5,1) (NAME(I),I=1,5),N
     1 FORMAT(5A4,I2)
       DO 60 I=1,8
    60 IVAR(I)=CHAR(15)
       PRINT 1010
       PRINT 1009,(NAME(I),I=1,5)
       PRINT 1011
       PRINT 1001
       DO 2 I = 1, N
       READ 3, (A(I,J), J=1,N)
       PRINT 1002, (A(I,J), J=1,N)
     2 CONTINUE
       READ 3, (B(I),I=1,N)
       PRINT 1004
       PRINT 1002, (B(I),I=1,N)
       READ 3,(C(I),I=1,N)
       PRINT 1007
       PRINT 1002, (C(I),I=1,N)
       READ 3, (AK(I), I=1,N)
       PRINT 1005
       PRINT 1002, (AK(I),I=1,N)
       READ 3, GAIN
       PRINT 1006, GAIN
       READ 3, (X(I),I=1,N)
       PRINT 1003
       PRINT 1002, (X(I),I=1,N)
       READ 3, TZERO, TF,DT,FREQ
       IFQ=FREQ
       PRINT 1000, TZERO, TF ,DT,IFQ
       PRINT 1011
       READ 1008, (IVAR(I),I=1,8)
       DO 40 I=1,8
       DO 30 J=1,15
       IF (IVAR(I)-CHAR(J)) 30,25,30
    25 IVAR(I)=J
       GO TO 40
    30 CONTINUE
    40 CONTINUE
       MIN=1
```

```
      MAX=8
      M=8
  419 DO 42 I=MIN,MAX
      IF(IVAR(I).NE.15) GO TO 42
      M=MAX-1
      IF(I.GT.M) GO TO 42
      DO 43 J=I,M
   43 IVAR(J)=IVAR(J+1)
      GO TO 431
   42 CONTINUE
      GO TO 432
  431 MIN=I
      MAX=M
      GO TO 419
  432 IPLOT = M
      IF(IPLOT.LT.2) GO TO 50
      LIM=IPLOT-1
      DO 44 I=1,LIM
      MIN=I+1
      DO 44 J=MIN,IPLOT
      IF(IVAR(I)-IVAR(J)) 44,44,45
   45 IHOLD=IVAR(I)
      IVAR(I)=IVAR(J)
      IVAR(J)=IHOLD
   44 CONTINUE
   50 CALL TRESP(A,X,B,AK,TZERO,TF,DT,IFQ,N,GAIN,C)
   20 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE TRESP(A,Y,B,AK,X,XMAX,H,IFREQ,N,GAIN,C)
C     THIS SUBROUTINE COMPUTES AND PLOTS TIME RESPONSE
C     USING CALCU, RUNGE, YDOT AND Y8VSX
      INTEGER CHAR(15)
      COMMON IPLOT,IVAR(10)
      DIMENSION SKJ(101,9),C(10)
      DIMENSION FN(10),        Y(10),A(10,10),B(10),AK(10)
      DATA CHAR(1),CHAR(2),CHAR(3),CHAR(4),CHAR(5),
     *CHAR(6),CHAR(7),CHAR(8),CHAR(9),CHAR(10),CHAR(11),
     *CHAR(12),CHAR(13),CHAR(14),CHAR(15)/1H1,1H2,1H3,1H4,
     *1H5,1H6,1H7,1H8,1H9,1HA,1HE,1HU,1HY,1HR,1H /
   24 FORMAT (2F10.0,2I10)
   25 FORMAT (8F10.0)
   28 FORMAT (//,8X,1HT,12X,4HY(T),10X,4HU(T),4X,
     *  6(5X,1HX,I1,4H(T) ,3X))
   29 FCRMAT(9(1PE14.6))
 1000 FORMAT(/,5X,33HMAXIMUM NUMBER OF POINTS EXCEEDED /)
      PRINT 28,(J,J=1,N)
      II=0
      J=0
      KOUNT=IFREQ
  300 CALL CALCU(Y,U,X,N,AK,GAIN,R,0)
      KOUNT = KOUNT + 1
      IF (KOUNT - IFREQ)  50, 350, 350
  350 KOUNT = 0
  450 P1=0.0
      DO 451 I=1,N
  451 P1=P1+C(I)*Y(I)
      PRINT 29,X,P1,U,(Y(M),M=1,N)
      WRITE (7,31)X,P1,(Y(M),M=1,4)
   31 FORMAT(6(1PE12.3))
      IF (IPLOT.EQ.0) GO TO 21
      J=J+1
      IF(J.GT.101) GO TO 222
      SKJ(J,1)=X
      DO 40 I=1,IPLOT
      MM=IVAR(I)
      IF(MM.EQ.0) GO TO 40
      IF(MM.GT.10) GO TO 35
      SKJ(J,I+1)=Y(MM)
      GO TO 40
   35 KNOW=MM-10
      GO TO (36,37,38,39), KNOW
   36 SKJ(J,I+1)=R-P1
      GO TO 40
   37 SKJ(J,I+1)=U
      GO TO 40
   38 SKJ(J,I+1)=P1
      GO TO 40
   39 SKJ(J,I+1)=R
   40 CONTINUE
   21 CONTINUE
   50 CALL RUNGE (N, FN, H, X, Y, L,II)
      IF(L-1) 100, 200, 100
  200 CALL CALCU(Y,U,X,N,AK,GAIN,R,1)
      CALL YDOT(A,Y,FN,B,U,N)
  550 GO TO 50
  222 PRINT 1000
      GO TO 400
 100    IF(X-XMAX) 300,300,400
  400 IF(IPLOT.EQ.0) GO TO 403
      PRINT 600
  600 FORMAT (1H1,50X,15HSYSTEM RESPONSE//)
      PRINT 601
  601 FORMAT (48X,8HVARIABLE,8X,6HSYMBOL//)
      DO 608 I=1,IPLOT
      MM=IVAR(I)
      IF(MM.GT.10) GO TO 603
      PRINT 602,IVAR(I),CHAR(MM)
  602 FORMAT (51X,1HX,I2,13X,A1)
      GO TO 608
  603 KK=IVAR(I)-10
```

```
      GO TO(604,605,606,607), KK
  604 PRINT 610
      GO TO 608
  605 PRINT 611
      GO TO 608
  606 PRINT 612
      GO TO 608
  607 PRINT 613
  608 CONTINUE
  610 FORMAT (50X,5HERROR,12X,1HE)
  611 FORMAT (49X,7HCONTROL,11X,1HU)
  612 FORMAT (50X,6HOUTPUT,11X,1HY)
  613 FORMAT (50X,5HINPUT,12X,1HR)
      CALL Y8VSX(SKJ,J,IPLOT,10)
  403 RETURN
      END
```

```
      SUBROUTINE CALCU(X,U,T,N,AK,GAIN,R,J)
C     THIS SUBROUTINE COMPUTES THE REFERENCE AND CONTROL
C     INPUTS
      DIMENSION X(10), AK(10)
C
C
C
      CALL RFIND(T,R)
C
C
C     END OF ROUTINE TO DEFINE R(T)
      U = R
      DO 1 I = 1, N
    1 U = U - AK(I)*X(I)
      U = U*GAIN
      RETURN
      END


      SUBROUTINE RUNGE (N,FN, H, X, Y, L,I)
C     FOURTH ORDER RUNGE KUTTA INTEGRATION ROUTINE
      DIMENSION Y(600), SAVEY(600), PHI(600), FN(8)
      I = I + 1
      GO TO ( 1, 2, 3, 4, 5) , I
    1 L = 1
      RETURN
    2 DO 600 J=1,N
      SAVEY(J) = Y(J)
      PHI(J) = FN(J)
  600 Y(J) = SAVEY(J) + .5*H*FN(J)
      X = X + .5*H
      L = 1

      RETURN
    3 DO 700 J=1,N
      PHI(J) = PHI(J) + 2.*FN(J)
  700 Y(J) = SAVEY(J) + .5*H*FN(J)
      L = 1
      RETURN
    4 DO 800 J=1,N
      PHI(J) = PHI(J) + 2.*FN(J)
  800 Y(J) = SAVEY(J) + H*FN(J)
      X = X + .5*H
      L = 1
      RETURN
    5 DO 900 J=1,N
  900 Y(J) = SAVEY(J) + (H/6.)*(PHI(J) + FN(J))
      L = 2
      I = 0
      RETURN
      END
```

```
      SUBROUTINE YDOT(A,Y,XDOT,B,U,N)
C     THIS SUBROUTINE IS USED TO COMPUTE DERIVATIVES FOR
C     RUNGE
      DIMENSION Y(10), A(10,10), B(10), XDOT(10)
      DO 2 I = 1, N
      XDOT(I) = 0.
      DO 1 J = 1, N
      XDOT(I) = XDOT(I) + A(I,J)*Y(J)
    1 CONTINUE
      XDOT(I) = XDOT(I) + B(I)*U
    2 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE Y8VSX(A,N,M,NGRID)
C     THIS SUBROUTINE PLOTS UP TO 8 VARIABLES VERSUS TIME
C     THIS IS BOTH A X-T AND X-Y PLOT ROUTINE
      COMMON IPLOT,IVAR(10)
      INTEGER CHAR(15)
      DIMENSION A(101,9),ABSCA(11),KAXIS(101),ORDIN(11),
     *TEMPY(9)
      DATA CHAR(1),CHAR(2),CHAR(3),CHAR(4),CHAR(5),
     *CHAR(6),CHAR(7),CHAR(8),CHAR(9),CHAR(10),CHAR(11),
     *CHAR(12),CHAR(13),CHAR(14),CHAR(15)/1H1,1H2,1H3,1H4,
     *1H5,1H6,1H7,1H8,1H9,1HA,1HE,1HU,1HY,1HR,1H /
      DATA ISTAR,II,IPER,IDASH,IBLANK/1H*,1HI,1H.,1H-,1H /
  100 FORMAT (////,9X, 11(1PE10.2))
  101 FORMAT(1PE13.2,2X,101A1)
  102 FORMAT(15X,101A1)
      YMAX=A(1,2)
      YMIN=A(1,2)
      MP1=M+1
      DO 4 J=2,MP1
      DO 4 I=1,N
      IF(YMAX-A(I,J)) 1,2,2
    1 YMAX=A(I,J)
    2 IF(YMIN-A(I,J)) 4,4,3
    3 YMIN=A(I,J)
    4 CONTINUE
    5 YSHFT=YMIN*100.0/(YMAX-YMIN)
    6 NM1=N-1
      DO 8 I=1,NM1
      IP1=I+1
      DO 8 K=IP1,N
      IF(A(K,1)-A(I,1)) 7,8,8
    7 DO 88 J=1,MP1
      ATEMP=A(I,J)
      A(I,J)=A(K,J)
      A(K,J)=ATEMP
   88 CONTINUE
    8 CONTINUE
      XMIN=A(1,1)
      XMAX=A(N,1)
      ABSCA(1)=XMIN
      ABSCA(11)=XMAX
      ORDIN(1)=YMIN
      ORDIN(11)=YMAX
      DO 9 I=2,10
      Z=I-1
      ABSCA(I)=(XMAX-XMIN)*Z/10.0+XMIN
    9 ORDIN(I)=(YMAX-YMIN)*Z/10.0+YMIN
      PRINT 100,(ORDIN(J),J=1,11)
      STEPX=(XMAX-XMIN)/100.0
      KDELX=1
      KLINE=1
      LINE=1
      DO 26 IND=1,N
      IF(NGRID.EQ.0) GO TO 200
```

```
      KSTEP=LINE
      GO TO 201
  200 KSTEP=(A(IND,1)-XMIN)/STEPX+1.5
  201 DO 10 J=2,MP1
   10 TEMPY(J)=A(IND,J)*100.0/(YMAX-YMIN)-YSHFT
   11 IF(KLINE-LINE) 12,12,18
   12 DO 13 I=2,100
   13 KAXIS(I) = IDASH
      DO 14 I=1,101,10
   14 KAXIS(I) = ISTAR
      IF(KSTEP-LINE) 15,15,17
   15 DO 16 I=2,MP1
      K = TEMPY(I) + 1.5
      MM=IVAR(I-1)
   16 KAXIS(K) = CHAR(MM)
   17 PRINT 101,ABSCA(KDELX),(KAXIS(J),J=1,101)
      IF(NGRID.EQ.0) GO TO 202
      KLINE=KLINE+NGRID
      ABSCA(KDELX)=A(KLINE,1)
      GO TO 24
  202 KLINE=KLINE+10
      KDELX=KDELX+1
      GO TO 24
   18 DO 19 I=2,100
   19 KAXIS(I) = IBLANK
      DO 20 I=1,101,10
   20 KAXIS(I) = IPER
      IF(KSTEP-LINE) 21,21,23
   21 DO 22 I=2,MP1
      K = TEMPY(I) + 1.5
      MM=IVAR(I-1)
   22 KAXIS(K) = CHAR(MM)
   23 PRINT 102,(KAXIS(J),J=1,101)
   24 LINE=LINE+1
      IF (LINE-102) 25,25,27
   25 IF(KSTEP-LINE) 26,11,11
   26 CONTINUE
   27 RETURN
      END
```

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Effects of short period angle of attack oscillation on air-to-ground weapons dive delivery accuracy.